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A Modified TOPSIS Procedure in Psychological Profiling for Crime Scene Analysis

Soumendra Goala[1], Pranjal Talukdar [2,*], Rupjit Saikia [3]

[1] North Eastern Regional Institute of Science and Technology, Nirjuli, Arunachal Pradesh, India
[1] Bir Raghab Moran Government Model College, Doomdooma, Assam, India
[1] Rajiv Gandhi Institute of Petroleum Technology, Sivsagar Campus, India

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ABSTRACT

Psychological profiling is an important technique in crime scene analysis, particularly when limited or no digital, physical, or forensic evidence is available at a crime scene. Psychological profiling can be defined as the process of identifying the probable physical, behavioral, and psychological characteristics of an unknown offender based on the actions and behavioral patterns exhibited during the commission of a crime. Such profiling can support investigators by narrowing the range of potential suspects and providing additional information about offender characteristics when conventional evidence is insufficient. This paper presents an extensive study of psychological profiling in the context of crime scene analysis and proposes a new decision-support methodology for evaluating potential offender profiles. The proposed methodology integrates the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) with a resemblance measure and addresses decision-making problems involving multiple ideal solutions. This integration enables alternative psychological profiles to be evaluated according to their resemblance to different ideal profiles derived from crime scene characteristics. To demonstrate the applicability of the proposed methodology, a detailed case study involving five crime cases is conducted. The psychological characteristics of the offenders are evaluated based on information obtained from the corresponding crime scene analyses. The results demonstrate how the proposed approach can systematically differentiate among potential psychological profiles and support the identification of offender characteristics across different crime scenarios.

1. Introduction

In a crime scene analysis, an investigator uses many techniques such as digital evidences, forensic evidences, eyewitnesses etc. to gather information about the offenders who might have committed the crimes. Woodhams *et al.,* [1] and Grubin *et al.,* [2] studied about situations in which investigatorsare not able to find any concrete or decisive evidences which might give them some lead about the offenders. Eze *et al.,* [3] and Rogers [4] described how an investigator may examine the crime scene by studying the probable actionsof the offender and try to find the behavioural pattern of the offender, which is broadly termed as psychological profiling. In short, psychological profiling is the process of generating a psychological pattern, behavioural pattern, physical portrait, employment

[*] *Corresponding author.*
E-mail address: pranjaltalukdar70@gmail.com

history, race, age etc. of an unknown offender using the available information about the crime he or she committed. In the absence of proper and solid evidences, in serial or serious offence, profiling techniques can give an investigator a lead and the profile can help to narrow down the list of suspects.

1.1 Uncertainty in constructing Psychological Profile

It is an established fact from psychology that, each person is different from the other in a psychological level. As a consequence, actions exhibit by an offender will lead to different profile for different offender. But this acts as a challenge in constructing a profile, Djartov*et al.,* [5] justified a generalized profiling technique is very hard to construct due to verity of psychological tendencies and uncountable shades of behavioural pattern of the offenders. For this situational uncertainty and lack of evidence theoreticaluncertainty always exist in the process of profiling technique.

Moreover, one piece of evidence on the crime scene can imply multiple behavioural elements of the unknown offender. Sometimes,slightestchange in the evidence may imply multiple behavioural patterns with different intensity. For these kinds of situations, it's very important to address the uncertainty which arises in crime scenes and their consequential behavioural pattern for efficient and effective construction of psychological profile of an unknown offender.

2. Literature review

Zadeh [6] introduced the notion of fuzzy sets and it became one of the most popular tools used in various field of sciences due to its applicability in addressing uncertainty. Later, Atanassov [7] generalized the concept of fuzzy set to Intuitionistic fuzzy set by introducing the notion non membership grade into the classical fuzzy set. Since then, it has been used almost every field of decision sciences due to its capability of addressing uncertainty. There are numerous numbers of decision-making methodologies among which TOPSIS (Technique for order preference by similarity to ideal solution) is one of the most important and widely used methods throughout the world since its introduction by Hwang and Yoon [8]. Recently, Kahraman *et al.,* [9], Tuğrul [10] and Garg and Arora [11] establishing the widespread utility of TOPSIS for complex decision-making under Intuitionistic uncertainty and validated the robust application of IFS combined with TOPSIS across different domains.

In the field of criminal investigation, detection and prediction, several studies have applied fuzzy multi-criteria decision making, fuzzy logic and pattern-recognition techniques. Quek *et al.,* [12] developed a fuzzy neural network for fingerprint matching. Grubesic [13] used fuzzy clustering for crime hot-spot detection. Li *et al.,* [14] developed an intelligent decision-support model for crime prevention, while Albertetti *et al.,* [15] applied a fuzzy multi-criteria framework to crime linkage. Gupta and Kumar [16] examined crime detection and prevention using social network analysis. Goala and Dutta [17] used a hesitant fuzzy distance measure and a fuzzy MCDM approach for crime linkage. Goala *et al.,* [18] introduced a resemblance function for intuitionistic fuzzy sets and applied it to crime linkage, and Goala *et al.,* [19] subsequently proposed another resemblance measure for serial-crime detection. More broadly, Burrell *et al.,* [20] reviewed behavioural crime-linkage methods and documented the use of similarity metrics, statistical approaches and fuzzy logic, while Bennell and Canter [21] used logistic regression and ROC analysis to test modus-operandi-based linkage of commercial burglaries. Dutta and Banik [22] introduced a new resemblance measure and applied it to crime linkage and psychological profiling.

3. Preliminary

In this section, some basic concept of fuzzy set, intuitionistic fuzzy sets and resemblance measures have been elaborated.

Definition 1. Fuzzy Set [6]: A fuzzy set is one which assigns grades of membership between 0 and 1 to objects within its universe of discourse. If is a universal set then a fuzzy set is defined by, its membership function

$$\mu_A: X \to [0,1] \tag{1}$$

Definition 2. Intuitionistic Fuzzy Set [7]: An Intuitionistic fuzzy set on a universe of discourse is defined as:

$$A = \{\langle x, (\mu_A(x), \nu_A(x))\rangle : x \in X\} \tag{2}$$

Where $\mu_A(x) \in [0,1]$ is called the "degree of membership" of x in A, $\nu_A(x) \in [0,1]$ is called the "degree of non-membership" of x in A, and $0 \le \mu_A(x) + \nu_A(x) \le 1$.

Here $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ is called hesitancy of$x$.$\pi_A(x)$ can considered as the degree of lack of commitment or uncertainty associated with the membership or non-membership in A.

Definition 3. Letandthen:

i. $A \subseteq B$ iff $\forall\, x \in X,\ \mu_A(x) \le \mu_B(x), \nu_A(x) \ge \nu_B(x)$ (3)

ii. $A = B$ iff $\forall\, x \in X,\ \mu_A(x) = \mu_B(x), \nu_A(x) = \nu_B(x)$ (4)

iii. $A^C = \{(x, \nu_A(x), \mu_A(x)) : x \in X\}$,Where $A^C$is the complement of A.

iv. $\cap A_i = \left\{\left(x, \wedge \mu_{A_i}(x), \vee \nu_{A_i}(x)\right) : x \in X\right\}$ (5)

v. $\cup A_i = \left\{\left(x, \vee \mu_{A_i}(x), \wedge \nu_{A_i}(x)\right) : x \in X\right\}$ (6)

3.1 Resemblance measure

Goala *et al.,* [18] observed that similarity measures have major disadvantages of dealing of fuzzy sets only in pairwise manner, but it cannot be used to quantify the similarity among more than two fuzzy sets. However, it is a common practice in real life situation to make comparison among more than two things for checking their equivalency or similarity. To tackle such situations and to remove this drawback of similarity measures, the concept of resemblance measure for IFSs is introduced.

Definition 4. [18].Consider$A = \left\{\langle x, \left(\mu_{A_1}(x), \nu_{A_1}(x)\right)\rangle, \langle x, \left(\mu_{A_2}(x), \nu_{A_2}(x)\right)\rangle, \cdots, \langle x, \left(\mu_{A_n}(x), \nu_{A_n}(x)\right)\rangle\right\}$be a collection of intuitionistic fuzzy sets. Resemblances measure is a function from A to [0,1]define as:

$$R(A) = \frac{1}{n}\sum_{i=1}^{n}\left(1 - \left|\bar{\mu}_{A_i} - \mu_{A_i}\right| - \left|\bar{\nu}_{A_i} - \nu_{A_i}\right|\right) \tag{7}$$

where, $\bar{\mu}_{A_i} = \frac{1}{n}\sum_{1=1}^{n}\mu_{A_i}$and $\bar{\nu}_{A_i} = \frac{1}{n}\sum_{1=1}^{n}\nu_{A_i}$.

To generalize the case resemblance function on $\tilde{A}_j = \left\{\left\langle x_j, \left(\mu_{A_{ji}}(x_j), \nu_{A_{ji}}(x_j)\right)\right\rangle : x_j \in X\right\}$ where $j = 1,2,\ldots,n$, Resemblance function on $\{\tilde{A}_1, \tilde{A}_2, \cdots, \tilde{A}_n\}$ can be defined as:

$$R(\{\tilde{A}_1, \tilde{A}_2, \cdots, \tilde{A}_n\}) = \begin{cases} \sum_{j=1}^{n} w_j \frac{1}{l_i}\sum_{i=1}^{l_i}\left(1 - \left|\bar{\mu}_{A_{ji}} - \mu_{A_{ji}}\right| - \left|\bar{\nu}_{A_{ji}} - \nu_{A_{ji}}\right|\right); n \ne 1 \\ 1, n = 1 \end{cases} \tag{8}$$

Where, $\bar{\mu}_{A_{ji}} = \frac{1}{n}\sum_{1=1}^{n}\mu_{A_{ji}}$and $\bar{\nu}_{A_{ji}} = \frac{1}{n}\sum_{1=1}^{n}\nu_{A_{ji}}$.

Where $l_i$is the number of intuitionistic fuzzy sets in $\tilde{A}_j$ and $w_j$is weight of the set $\tilde{A}_j$and $w_1 + w_2 + \cdots + w_n = 1$.

4. Motivation of the study

It is mentioned in section 1 that why it is very difficult to construct a generalized methodology for psychological profiling due to several types of uncertainty which arises during investigation as well as in analysis. In addition, there are only a few studies can be found for mathematical modelling on psychological profiling. This research gap motivates us to work in this particular area.

During psychological profiling sometimes one evidence or physical action of an offender may correspond to multiple behavioural patterns. Li *et al.,* [23] and Joshi *et al.,* [24] mentioned how the Ideal solution of the TOPSIS procedure may have more than one input. For example, if an offender does not use his own weapon or tools considered as disorganized behaviour most of the time, but there are some instances where the offender uses tools which were present in the crime scene and this behaviour corresponds to organized and intelligent behaviour. To tackle such issues an investigator might need more than one ideal situation or solution for one particular action or evidence. This type of situation has never been addressed by any researcher till now. Therefore, we are strongly motivated to work in this topic to develop a new modified TOPSIS procedure with blending of resemblance measure for psychological profiling.

5. Methodology

5.1 The problem statement

In crime scene analysis, an investigator observes and studies the physical evidences. Then the evidences are coded and rearranged according to convenience and objective. Then the evidences are matched with standard prototype behavioural elements and checked the evidences converge or tend to which behavioural pattern. As it is already mentioned that the evidences and behavioural patterns are not specific and uncertain most of the time, fuzzy Intuitionistic set has been used to address uncertainty of the evidences. For comparing the evidences with the standard prototypes of behavioural elements fuzzy, TOPSIS procedure has been used with modification via resemblance measure.

5.2 Methodology

Step 1. Consider a set of crimestaken under.

Step 2. List the set of actionsrelated to all the crimes taken under study.

Step 3. Evaluate or assign weight of the actions as .

Step 4. The crimes and the action are expressed in decision matrix as follows

$$\begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_m \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{bmatrix} L_{11} & L_{12} & \cdots & L_{1n} \\ L_{21} & L_{22} & \cdots & L_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ L_{m1} & L_{m2} & \cdots & L_{mn} \end{bmatrix} \end{array} \tag{9}$$

Where, $L_{ij}$is the intensity/degree of existence/degree of presence of the action $A_j$in the crime C_i .

Step 5. Assign eachby an appropriate IFSs to construct a fuzzy decision matrix as:

$$\begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_m \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{bmatrix} \tilde{I}_{11} & \tilde{I}_{12} & \cdots & \tilde{I}_{1n} \\ \tilde{I}_{21} & \tilde{I}_{22} & \cdots & \tilde{I}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{I}_{m1} & \tilde{I}_{m2} & \cdots & \tilde{I}_{mn} \end{bmatrix} \end{array} \tag{10}$$

Where, $\tilde{I}_{ij}$become the IFSs that represent the degree to which the action $A_j$was present the crime C_i.

Step 6. The crimes are expressed in terms of IFSs as follows$C_j = \{\langle A_i, \tilde{I}_{ij}\rangle | A_i \in A\}$where$I_{ij} \to [0,1]$; $i = 1,2,\cdots m$ and $j = 1,2,\cdots n$.

Step 7. For each behavioural pattern construct a finite number of different positive ideal situation and different negative ideal situation as $PIS_p(B_j) = \{\langle A_i, I_j^{+}\rangle\}$and $NIS_q(B_j) = \{\langle A_i, I_j^{-}\rangle\}$; $p = 1,2,\cdots,p_j$, $q = 1,2,\cdots,q_j$, where p_j is the number of positive ideal situation for the behavioral pattern B_j and q_j is the number of negative ideal situation for the behavioural pattern B_j.

Step 8. Compute Resemblance measure for the crime with all the positive ideal situationsand all negative ideal situation.

Step 9. Compute the closeness coefficient of each behaviouralpattern with the crime

$$CC_{ij} = \frac{R\{C_i, \cup_p PIS_p(B_j)\}}{R\{C_i, \cup_q NIS_q(B_j)\} + d\{C_i, \cup_p PIS_p(B_j)\}} \tag{11}$$

Step 10. Rank each behavioural pattern using the closeness coefficient and determine their presence in the offender of the crime scene.

5.3 Novelty and advantage of the methodology

The TOPSIS methodology integrated with Intuitionistic Fuzzy Sets (IFS) introduces a strong approach in managing the inherent ambiguities of criminal investigations. The traditional TOPSIS procedure evaluates alternatives based on their distance or similarity to a single Positive Ideal Solution (PIS) and a Negative Ideal Solution (NIS). But psychological profiling is a highly dynamic situation where a single behavioural pattern might be a consequence of multiple and divergent offender actions. Therefore, the classical pairwise distance or similarity measures becomes mathematically insufficient when multiple ideal situations present.

This methodology introduced in the manuscript addresses these theoretical and practical gaps and has advantages in case of multiple ideal situations for the following reasons:

i. Multiple Ideal AssessmentCapability:Themodified TOPSIS method can simultaneously evaluate closeness coefficients against multiple positive and negative ideal situations by replacing traditional similaritymeasure with a generalized resemblance measure which reflects the varied nature of criminal behaviour.
ii. Overcoming Pairwise Limitations: Standard similarity measures are fundamentally restricted to pairwise comparisons between two sets. The resemblance measure acts as an advanced tool that is capable of quantifying similarities across an entire collection of fuzzy behavioural sets simultaneously.

6. A Case Study

Let us consider description of the following five crimes:

Crime scene 1: Someone came through the by unlocking the inner lock using some tools like screw-driver. He or she or they took cash and jewellery but did not touch other things much and did not damaged other objects accept locker in the bedroom and suitcases.

Crime scene 2: Someone came into an abundant house by breaking the front door of the house using some tricks. It is not known whether they used any equipment or not. They took jewellery and it's less likely that they took anything more than that. Also, no sign of damaged can been seen in the house.

Crime scene 3: Someone came into an office through the roof and no evidence of found how they entered and if they used any mechanical tools or not. They took all cash with them and most probably did not touch anything else. No other damage can be seen in that office due to the theft.

Crime scene 4: Someone entered in the house via front door by breaking it, broke the lock by some rodapplying average physical strength. They took only cash and damaged other things by burning down the room badly.It’s not known whether they took something else or not.

Crime scene 5: Someone enter into a house by breaking a window totally using physical strength. They broke a locker by some kind of rod and cutter or tools and took cash, gold and silver jewellery items. They damaged the house and other objects while committing the crimes also.

Now from all the crimes there are 6 common factors/evidences/criteria can be found with different intensity or degree, which are:

A_1: Physical force

A_2: Techniques and Tricks

A_3: Mechanical tools

A_4: Theft of Cash/Jewelry

A_5: Theft of whatever available on the scene

A_6: Damaged objects

Now, all the crime scenes can be represented in Table 1.Using the physical actions of the unknown offenders and their degree or extent of those actions in the crime scenes:

Table 1
Description of five crimes

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	Low	High	High	Very High	Low	Low
C_2	High	Very High	Uncertain	Very High	Very Low	Very Low
C_3	High	Uncertain	Average	Very High	Low	Low
C_4	Very High	Very Low	Very Low	Average	Uncertain	High
C_5	Very High	High	Low	High	Very Low	Very High

From the crime scene, analysis has been done and behavioural pattern of the unknown offenders has been portrayed. There is a wide category of two behaviouralpatternlabelled as organized crime and disorganized crime.

The disorganized offender, as the name suggests they are usually unplanned in their action and have the following main characteristics:

i. Low intelligence
ii. Severe psychopathic disturbance
iii. Earlier contact with mental health system
iv. Little or no premeditation
v. Whatever found at hand used as weapon
vi. Left the immediate weapon at the scene
vii. The victim selected at random more or less
viii. Quick overpower over the victim
ix. Extreme brutality in his/her action

Similarly, the organized offenders are usually commits through planning and have the following main characteristics.

i. Reasonably intelligent
ii. Under achiever with sporadic education
iii. Usually have employment history
iv. Has social connections and least has face value in his/her society
v. Psychopathic personality
vi. Signs of planning and control can be seen from the crime scene

vii. Usually bring their own weapon
viii. take with them after the crime
ix. Victims are targeted stranger most of the time
x. Control the victim by manipulation and or by threatening
xi. More forensic awareness can be seen from the action of the offender.

For the case study the two categoriesare again divided into four categories for our own convenience:

i. Highly Organized behaviour
ii. Average Organized behaviour
iii. Low Organized behaviour
iv. Disorganized behaviour

Now, from the available data/description about the crime scenes, we have to construct a psychological profile using embedding resemblance measure in fuzzy TOPSIS method.

Now using the investigative psychology, we have constructed three positive ideal situation and two negative ideal situations for Highly organized behaviour, two positive ideal situation and two negative ideal situationsfor Average organized behaviour, two positive ideal situation and two negative ideal situationsfor low organized behaviourand three positive ideal situation and three negative ideal situationsfordisorganizedbehaviour.The situations are represented in the following tables (Table 2):

Table 2
Positive ideal situation and three negative ideal situations

		A_1	A_2	A_3	A_4	A_5	A_6
Highly Organized behaviour (B_1)	PIS_1	High	Very High	High	High	Very Low	Very Low
	PIS_2	Average	Very High	Very High	Very High	Very Low	Very Low
	PIS_3	Average	High	High	Average	Very Low	Very Low
	NIS_1	Very High	Very Low	Average	High	Very High	Very High
	NIS_2	Very High	Very Low	Average	Very High	Very High	Very High
Average Organized behaviour (B_2)	PIS_1	Average	Average	Average	High	Average	Average
	PIS_2	Average	Average	Average	Average	Average	Average
	NIS_1	Average	Average	Average	Low	Average	Average
	NIS_2	Average	Average	Average	Average	Average	Average
Low Organized behaviour (B_3)	PIS_1	Very Low	Very Low	Average	Very High	Very High	Very High
	PIS_2	Low	Very Low	Average	High	High	Very High
	NIS_1	Very Low	Low	Average	High	Low	Low
	NIS_2	Low	Very High	High	Very High	Very Low	Very Low
Disorganized behaviour (B_4)	PIS_1	Very High	Very Low	Very Low	Average	Very High	Very High
	PIS_2	High	Low	Low	Average	High	High
	PIS_3	Average	Low	Very Low	Average	High	High
	NIS_1	Very Low	Very High	Very High	Average	Very Low	Very Low
	NIS_2	Low	High	High	Average	Low	Low
	NIS_3	Average	High	Very High	Average	Low	Low

Now, the linguistic variables used in Table 1 and Table 2 are fuzzified using their corresponding Intuitionistic membership degrees which is given in Table 3. The fuzzified data for the crime scenes and the ideal situations are given in Table 4 and Table 5.

Table 3
Linguistic variables and their corresponding IFSs

Linguistic variables	Membership degrees
Very High	(0.95, 0.05)
High	(0.75, 0.25)
Average	(0.5, 0.5)
Low	(0.25, 0.75)
Very Low	(0.05, 0.95)
Uncertain	(0.1,0.1)

Table 4
Fuzzy decision matrix

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	(0.25, 0.75)	(0.75, 0.25)	(0.75, 0.25)	(0.95, 0.05)	(0.25, 0.75)	(0.25, 0.75)
C_2	(0.75, 0.25)	(0.95, 0.05)	(0.1,0.1)	(0.95, 0.05)	(0.05, 0.95)	(0.05, 0.95)
C_3	(0.75, 0.25)	(0.1,0.1)	(0.5, 0.5)	(0.95, 0.05)	(0.25, 0.75)	(0.25, 0.75)
C_4	(0.95, 0.05)	(0.05, 0.95)	(0.05, 0.95)	(0.5, 0.5)	(0.1,0.1)	(0.75, 0.25)
C_5	(0.95, 0.05)	(0.75, 0.25)	(0.25, 0.75)	(0.1,0.1)	(0.05, 0.95)	(0.95, 0.05)

Table 5
Fuzzified PIS and NIS for behavioural pattern

		A_1	A_2	A_3	A_4	A_5	A_6
Highly Organized behaviour (B_1)	PIS_1	(0.75, 0.25)	(0.95, 0.05)	(0.75, 0.25)	(0.75, 0.25)	(0.05, 0.95)	(0.05, 0.95)
	PIS_2	(0.5, 0.5)	(0.1,0.1)	(0.1,0.1)	(0.1,0.1)	(0.05, 0.95)	(0.05, 0.95)
	PIS_3	(0.5, 0.5)	(0.75, 0.25)	(0.75, 0.25)	(0.5, 0.5)	(0.05, 0.95)	(0.05, 0.95)
	NIS_1	(0.95, 0.05)	(0.05, 0.95)	(0.5, 0.5)	(0.75, 0.25)	(0.95, 0.05)	(0.95, 0.05)
	NIS_2	(0.95, 0.05)	(0.05, 0.95)	(0.5, 0.5)	(0.95, 0.05)	(0.95, 0.05)	(0.95, 0.05)
Average Organized behaviour (B_2)	PIS_1	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.75, 0.25)	(0.5, 0.5)	(0.5, 0.5)
	PIS_2	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)
	NIS_1	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.25, 0.75)	(0.5, 0.5)	(0.5, 0.5)
	NIS_2	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)	(0.5, 0.5)
Low Organized behaviour (B_3)	PIS_1	(0.05, 0.95)	(0.05, 0.95)	(0.5, 0.5)	(0.95, 0.05)	(0.95, 0.05)	(0.95, 0.05)
	PIS_2	(0.25, 0.75)	(0.05, 0.95)	(0.5, 0.5)	(0.75, 0.25)	(0.75, 0.25)	(0.95, 0.05)
	NIS_1	(0.05, 0.95)	(0.25, 0.75)	(0.5, 0.5)	(0.75, 0.25)	(0.25, 0.75)	(0.25, 0.75)
	NIS_2	(0.25, 0.75)	(0.95, 0.05)	(0.75, 0.25)	(0.95, 0.05)	(0.05, 0.95)	(0.05, 0.95)
Disorganized behaviour (B_4)	PIS_1	(0.95, 0.05)	(0.05, 0.95)	(0.05, 0.95)	(0.5, 0.5)	(0.95, 0.05)	(0.95, 0.05)
	PIS_2	(0.75, 0.25)	(0.25, 0.75)	(0.25, 0.75)	(0.5, 0.5)	(0.75, 0.25)	(0.75, 0.25)
	PIS_3	(0.5, 0.5)	(0.25, 0.75)	(0.05, 0.95)	(0.5, 0.5)	(0.75, 0.25)	(0.75, 0.25)
	NIS_1	(0.05, 0.95)	(0.95, 0.05)	(0.95, 0.05)	(0.5, 0.5)	(0.05, 0.95)	(0.05, 0.95)
	NIS_2	(0.25, 0.75)	(0.75, 0.25)	(0.75, 0.25)	(0.5, 0.5)	(0.25, 0.75)	(0.25, 0.75)
	NIS_3	(0.5, 0.5)	(0.75, 0.25)	(0.95, 0.05)	(0.5, 0.5)	(0.25, 0.75)	(0.25, 0.75)

Now, the closeness coefficients are evaluated for each behavioural pattern as shown in Table 6 and ranking can have evaluated for behavioural patterns for each crime scene scenes. The closeness coefficients of the behavioural patterns are given in Table 6.

The graphical representation for the comparison of different behaviours in the Crime scene 1, on the basis of closeness coefficient is shown in Figure 1. It can be observed that the offender who committed the crime C_1might have average level of organized behavior with highest closeness coefficient 0.746296296. The immediate lesser closeness coefficient is 0.688888889 corresponds to low organized behaviour and subsequently the ranking of the behavioural pattern can be obtained.

Table 6
Closeness coefficient between the crimes and behavioural pattern

Types of behaviour	CC for C_1	CC for C_2	CC for C_3	CC for C_4	CC for C_5
Highly Organized behaviour(B_1)	0.657175926	0.650636574	0.713541667	0.662384259	0.695833333
Average Organized behaviour(B_2)	0.746296296	0.635185185	0.82037037	0.666666667	0.657407407
Low Organized behaviour(B_3)	0.688888889	0.546296296	0.685185185	0.611111111	0.609259259
Disorganized behaviour(B_4)	0.68437500	0.630208333	0.694791667	0.688541667	0.648958333

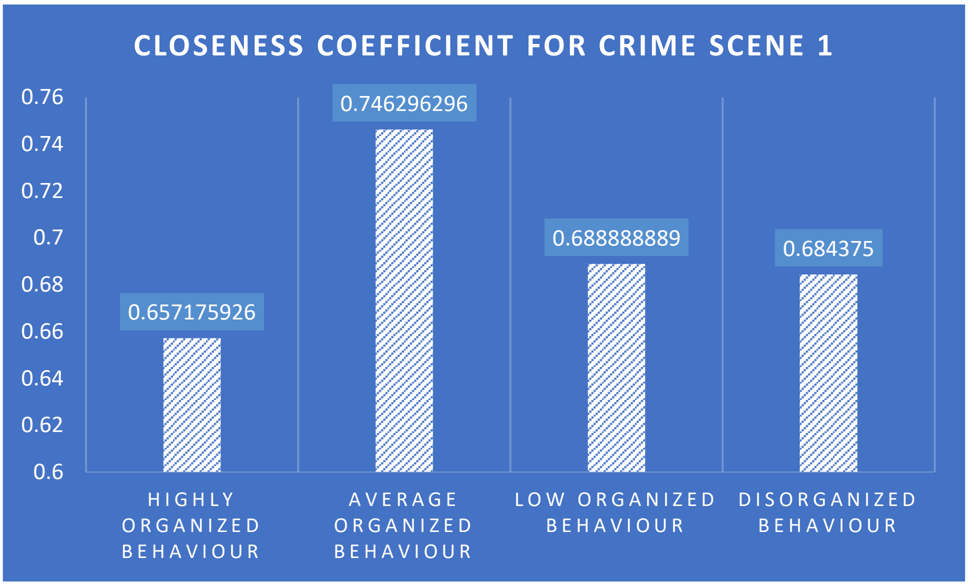

Fig. 1. Closeness coefficient of psychological profiling elements for Crime scene 1

The graphical representation for the comparison of different behaviours in the Crime scene 2, on the basis of closeness coefficient is shown in Figure 2. Similarly, the offender who committed the crime C_2might have highly organized behavior with highest closeness coefficient 0.650636574. The immediate lesser closeness coefficient is 0.635185185corresponds to average organized behaviour and the other behavioural patterns can be ranked accordingly.

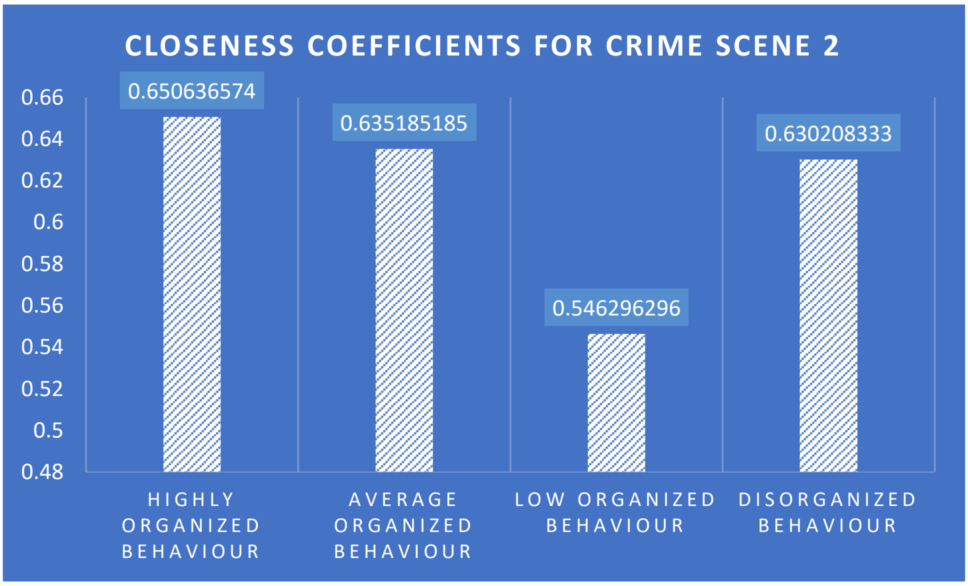

Fig. 2. Closeness coefficient of psychological profiling elements for Crime scene 2

The graphical representation for the comparison of different behaviours in the Crime scene 3, on the basis of closeness coefficient is shown in Figure 3.For the crime sceneC_3, the dominant behavioral pattern is the average organized behaviourwithhighest closeness coefficient 0.82037037. Similarly, other behavioural patterns can be ranked accordingly.

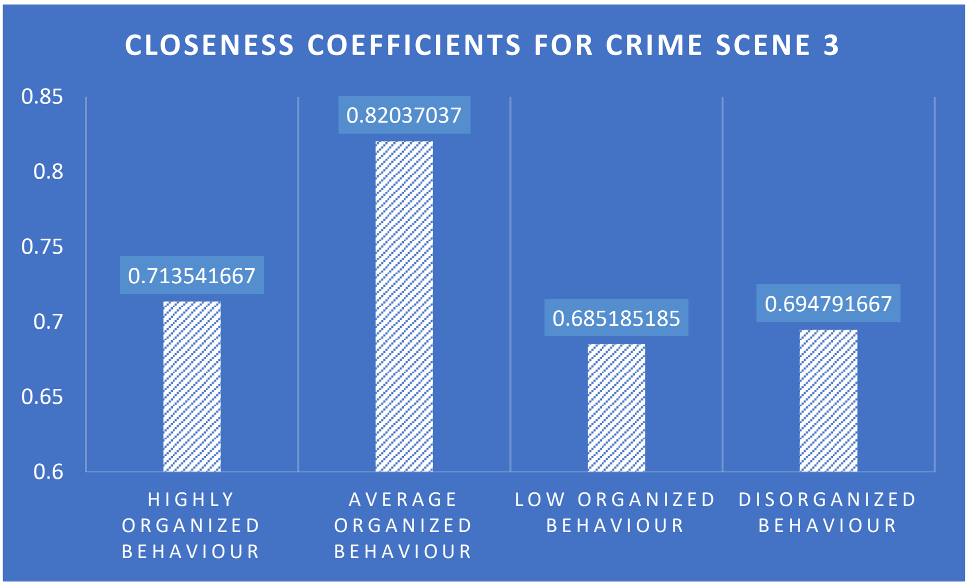

Fig. 3. Closeness coefficient of psychological profiling elements for Crime scene 3

The graphical representation for the comparison of different behaviours in the Crime scene 4, on the basis of closeness coefficient is shown in Figure 4. For the crime scene C_4, the dominant behavioral pattern is the disorganized behavior with highest closeness coefficient 0.688541667. Similarly, other behavioural patterns can be ranked accordingly.

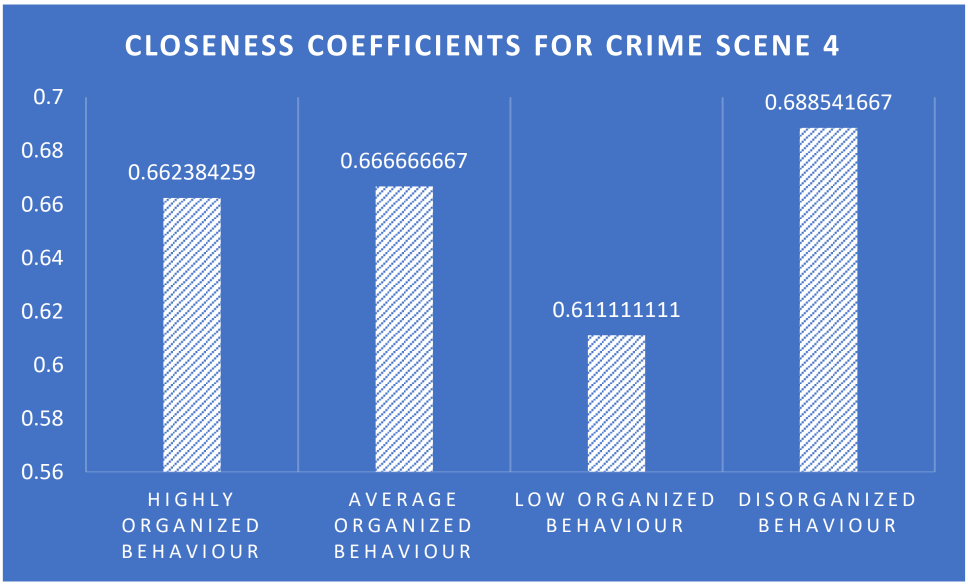

Fig. 4. Closeness coefficient of psychological profiling elements for Crime scene 4

The graphical representation for the comparison of different behaviours in the Crime scene 5, on the basis of closeness coefficient is shown in Figure 5. For the crime scene C_5, the dominant behavioral pattern is the highly organized behavior with highest closeness coefficient 0.695833333. Similarly, other behavioural patterns can be ranked accordingly.

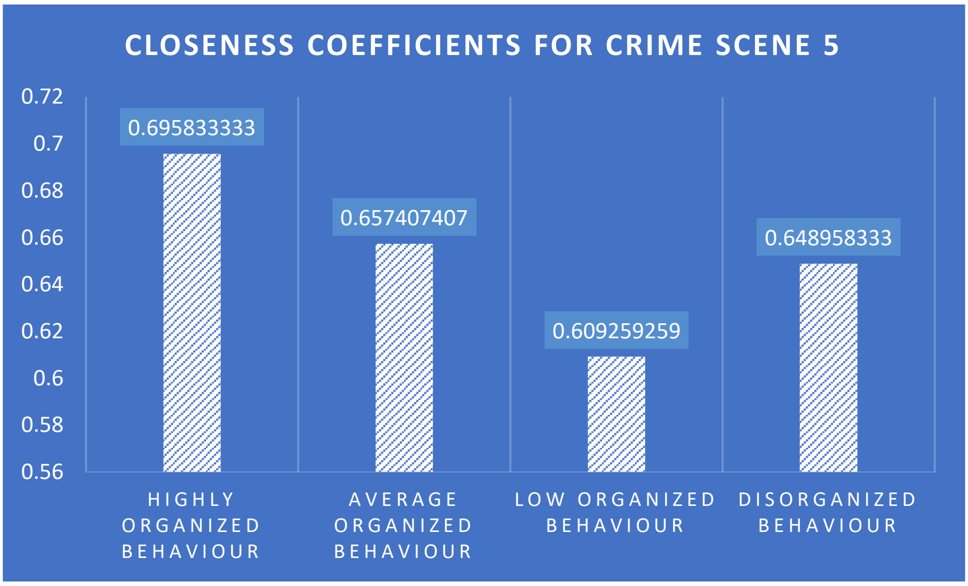

Fig. 5. Closeness coefficient of psychological profiling elements for Crime scene 5

7. Discussion and analysis

Now, from the case study,it can be seen that for the crime scenes C_1, $C_2$and $C_5$the dominant behavioral pattern is highly organized behavior. This means, the offender who committed the crimes $C_1$and C_5should be highly intelligent, should have an employment history, has social connections and least has face value in his/her society, he/she executed the crime with proper planning and control and might brought their own weapon. For the crime scene C_4, the dominant behavioral pattern came out to be disorganized behavior. Therefore, it can be concluded that the offender who committed the crime should be less intelligent, impulsive, might have severe psychopathic disturbance, whatever found at hand used as weapon or tool and extreme brutality in his/her action. For the crime scene C_3, the dominant behavioral pattern came out to be average organized behavior. Therefore, it can be concluded that the offender who committed the crime should be average level of intelligent, less impulsive, might have severe psychopathic disturbance and proceeded with little or no weapon or tool with him. It can be noticed that sometimes the difference between closeness coefficients is very less. For example, for crime scene C_4 the closeness coefficient for highly organized behavior is 0.662384259 and for average organized behaviour is 0.66666667, which are very close. In that case an investigator advised to takethose situations into consideration, otherwise improper and illogical resultmight cause faulty decision-making process in profiling.

8. Conclusion

In this paper, a study has been carried outon psychological profiling under intuitionistic fuzzy environment. For generating psychological profile depending upon the crime scene analysis TOPSIS procedure has been modified by incorporating resemblance measure. In this new method, a special type of situation is taken into consideration where there may be more than one ideal solution or situations. The classical TOPSIS procedure is not applicable in such types of situations, whereas the modified procedure can tackle such situation easily. To show the usability and applicability of this methodology a case study has been carried on five crimes and generated psychological profile for each criminal case.

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Conflicts of Interest

The authors declare no conflicts of interest.

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