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RESEARCH ARTICLE

VlseKriterijumska Optimizacija I Kompromisno Resenj (VIKOR) Method: MCDM Approach for the Medical Diagnosis of Vector-Borne Diseases

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Abstract: In dealing with the medical decision-making with uncertainty, clinical diagnosis of diseases is very difficult without the intervention of domain experts. In this work, an approach has been developed that provides handheld support to the medical practitioners for the medical diagnosis of diseases. With the assistance of the three domain experts of Delhi-based Government hospital, linguistic information of four patients has been collected under intuitionistic fuzzy environment. VlseKriterijumska Optimizacija I Kompromisno Resenj method, a multi-criteria decision-making technique, is utilized to rank the diseases among the patients. It seems that the conclusive outcomes of the investigation are same as diagnosed by medical specialists.

Keywords: multi-criteria decision-making (MCDM), generalized fuzzy sets, medical diagnosis, decision-making, computational technique

1. Introduction

Since the inception of computers, many scientific and decision support tools have been developed that make the life of decision makers easy to take decisions under unfavorable circumstances. The developments of many soft computing techniques such as fuzzy theory and its generalization provide hand held support to the decision theory and acts as an interface that contributes much in solving real-life problems with uncertain and imprecise information.

For such situations, Zadeh [1] introduced the generalized concept of classical set theory as fuzzy set (FS) theory, which has the inbuilt capability to represent incomplete information. From the past many decades, fuzzy theory and its generalized versions have been emerged as a potential area of interdisciplinary research. Among this, intuitionistic fuzzy set (IFS) theory introduced by Atanassov [2] is one such generalization, which is described by membership as well as non-membership grades, respectively, and described the fuzzy character more comprehensively in special situations ranging from market prediction to medical diagnosis. Zadeh [3] and Zimmermann [4] anticipated that fuzzy theory handles the problems of medical diagnosis very well, as it is a tool that reasoning like humans for dealing with vague, uncertain and imprecise situations. The primary characteristic of fuzzy theory is its interpretability, which accepts the knowledge in linguistic ways and allows the system to describe simple human-friendly rules, a key factor in medical discipline. Many fuzzy-based models intervene, varying as per important symptoms, symptom patterns of different diseases, relationship between diseases, and the hypothesis of disease stages, preliminary diagnosis, and final diagnosis. These models form the initial basis for the diseases, which might be iterated and configured as per the requirement. Sanchez [5] proposed the fuzzy-based model, which represents the knowledge base by establishing a fuzzy max-min relation between the symptom and the disease.

Multi-criteria decision-making (MCDM) is the branch of decision-making for designing computational tools to support the evaluation of performance criteria with an aim to solve real-world problems. Since last six decades, MCDM techniques support the researchers in decision-making processes that classify the set of alternatives into manageable groups to rank as per the order of preference. These models have criteria in the form of verbal/linguistic variables, which are used under critical or complex situations and do not contain mathematical equations. In this paper, a kind of MCDM technique has been used to rank the diseases based on the collected linguistic information.

2. Literature Review

Adlassnig and Kolarz as well as Adlassnig [6, 7] proposed fuzzy-based computer program that assists the medical practitioners for the diagnosis of diseases. Atanassov [8] and Bustince et al. [9] developed the theory to handle more complex decision-making problems. The concept of vague set has been

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introduced by Gau and Buehrer [10], which is an equivalence of IFS by Bustince and Burillo [11]. Kapur [12] proposed certain fuzzy information theoretic measures that give birth to the new discipline of fuzzy information theory. De et al. [13] developed new categories of IFS operators such as concentration, dilation, and normalization. Based on vague sets and IFS, Atanassov et al. [14], Chen and Tan [15], Hong and Choi [16], and Szmidt and Kacprzyk [17] developed some approximate techniques for handling MCDM problems under IF environment. Researchers such as Delgado et al. [18], Bordogna and Pasi [19], Fisher [20], Herrera and Herrera-Viedma [21–23], Karsak and Tolga [24], Law [25], Lee [26], Roubens [27], Sanchez [28], Yager [29, 30], Zeng et al. [31], Zhang and Lu [32], Chen and Hwang [33], Kacprzyk et al. [34], Fodor and Runens [35], and Bordogna et al. [36] used the application of FSs in the MCDM problems for decision-making purposes across disciplines. Kumar et al. [37] used prioritized operators for the medical diagnosis of diseases in IF environment. Kumar and Jain [38] proposed fuzzy medical decision-making system for the diagnosis of type of malaria. Verma and Sharma [39, 40] proposed exponential IF information measures that have applications across domain. Parkash et al. [41] introduced new fuzzy-based measures for the study of maximum-weighted entropy principle. Taruna et al. [42] proposed generalized information fuzzy distance measures for medical diagnosis. Diaby and Goeree [43] proposed three stages of the MCDM model, and Roy [44] addresses four types of MCDM problems such as choice, sorting, ranking, and description. Techniques such as technique for order preference by similarity to ideal solution (TOPSIS) and VlseKriterijumska Optimizacija I Kompromisno Resenj (VIKOR) give promising results and have applications in manufacturing, healthcare systems, medical decision-making, decision-making, etc. Nădăban et al. [45], Mahdavi et al. [46], and Lu et al. [47, 48] used fuzzy MCDM TOPSIS technique to propose decision support system. Opricovic [49] developed VIKOR method, a multi-criteria optimization technique to find compromise solution. The method provides decision support system for the selection of most suitable alternative for the evaluation and comparison of available options. Çakır [50], Zhang et al. [51], and Rezaei et al. [52] stated that VIKOR is sometimes known as ideal point technique to determine positive as well as negative ideal solution in the first step and arranged the ideal scheme on the basis of closeness coefficient of alternatives. This is suitable for situations, where profit is maximum and risk is as less as possible. Hwang and Masud [53] pointed out that right assessment of criteria weights is very important in MCDM problems, as the variation of weight values affects the ranking of alternatives. According to Ma et al. [54], Saaty [55], and Hwang and Lin [56], the determination of attribute weights is categorized as subjective, objective, and integrated, which are based on the information gathered through the sources. The calculation of weights from preference information on attributes has been calculated through subjective approaches, and the determination of weights directly from decision matrix has been analyzed using objective approaches, whereas integrated approach determines the weights of attributes by using both subjective and objective information. Subjective and objective approaches have been used in this work to determine criteria weights. Any form of illness present in the human body is deadly, and the trajectory of the disease from diagnosis to the treatment passes through certain challenging decisions. Information-based management system could be the key factor in understanding the diagnosis of diseases, making decisions and if possible, reconfigure the treatment.

3. Vector-Borne Diseases

Vector-borne disease (VBD) spreads out by the transmission of an infectious humans/animals through blood-feeding arthropods, such as mosquitoes, ticks, snails, and lice, that give a severe threat to the human beings. These diseases alone are responsible for the major causes of illness and death, particularly in tropical and subtropical countries. World Health Organization [57] reported 12 major diseases caused by vectors globally with a death toll of 0.7 million annually, which account for more than 17% of all infectious diseases. Out of which, malaria causes more than 0.4 million deaths every year, majority of being are children below 5 years of age and approximately 96 million cases annually are at risk of contracting dengue. Since 2014, dengue, malaria, chikungunya (yellow fever), and zika have affected people over the globe. The cases of these virus are spreading every year and are increasing with exponential pace. WHO started various awareness program to tackle VBDs and provide support to vector-affected countries in many ways, but this is not sufficient to fight with the diseases. A systematic approach is required to tackle the needful situation and provide the right solution to the problem. The diagnosis of these diseases is possible by means of both clinical and laboratory findings; however, various laboratory tests have been used to acknowledge the availability of type of different type of VBD and in many places such facilities are not frequently available. In clinical surveillances, laboratory information is not essential and symptoms of most of the diseases are common. The relative treatment procedure could be delayed, if right and timely diagnosis of VBDs cannot be found. In remote places and other primary healthcare centers, there is scarcity of diagnostic facilities. Therefore, there is an utmost requirement of some dynamic system, which intervenes with the available information and gives the right results. In Tanios et al. [58] and Kahraman et al. [59], it is necessary to find the suitable technique, which not only reduces the errors but also easy to perform. The chosen method should increase the credibility of the solution and minimize the responsibility of the decision maker to guarantee a solution. Various multi-criteria methods used for the optimization of healthcare systems have been discussed by Dolan [60], Marsh et al. [61], Adunlin et al. [62], Gutknecht et al. [63], Mühlbacher and Kaczynski [64], Liu et al. [65], Dehe and Bamford [66], Delice and Zegerek [67], and Thokala et al. [68]. Various MCDM approaches in medical diagnosis have been proposed by Diaby and Goeree [43], Lu et al. [47, 48], Hongoh et al. [69], Kulak et al. [70], Diaby et al. [71], Padma and Balasubramanie [72], Goetghebeur et al. [73], Ozkan [74], Hancerliogullari et al. [75], Carnero and Gomez [76], and Sustersic et al. [77] that support the treatment of diseases. In this work, a robust multi-criteria optimization VIKOR method for the diagnosis of VBDs has been proposed with intuitionistic fuzzy (IF)-based information.

4. Preliminaries

Crisp set is a conventional bivalent set that contains an element, which is either a member of set or not.

FSs are introduced by Zadeh [1] as an extension of the classical notion of sets whose elements have degrees of membership and is defined as:

A FS A defined in a discrete universe of discourse $X = \{x_1, x_2, \ldots\ldots, x_n\}$ is given as: $A = \{< x,\ \mu_A(x)\ > :\ x \in X\}$

where $\mu_A : X \rightarrow [0,\ 1]$ is the membership function of set A and $\mu_A(x)$ is called the grade of membership of $x \in X$ in A.

IF sets are introduced by Atanassov [2], a generalization of FS and is defined as:

An IFS A in $X = \{x_1, x_2, \ldots.., x_n\}$ is given as: $A = \{< x,\ \mu_A(x),\ \nu_A(x) > \mid x \in X\}$ described by membership function $\mu_A(x) : X \to [0, 1]$ and non-membership function $\nu_A(x) : X \to [0, 1]$ of the element $x \in X$, where the function $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ is defined as intuitionistic or hesitation index of x in A. In limiting case, if $\pi_A(x) = 0$, IFS reduces automatically to FS.

5. Mathematical Expressions

Let $G_i(\ i = 1, \ldots\ldots, m)$ be the set of alternatives with associated criteria as $C_j(j = 1, \ldots.., n)$ chosen by the domain experts $M_k(k = 1, \ldots.., d)$ of the problem in hand. Each expert M_k is allocated with a weight $\theta_k > 0$ such that $\sum_{k=1}^{d} \theta_k = 1$ which reflects the relative significance.

Suppose $r_{ij} = (\mu_{ij}^k, \nu_{ij}^k)$ be the IFN assigned to information given by the expert M_k for each alternative G_i with respect to the criteria C_j.

Now the aggregated IF rating of (r_{ij}) alternatives with respect to each criteria can be evaluated with the help of the operator introduced by Xia and Xu [78] as:

$$r_{ij} = \left\langle \frac{\prod_{k=1}^{d}\left(\mu_{ij}^k\right)^{\theta_k}}{\prod_{k=1}^{d}(\mu_{ij}^k)^{\theta_k} + \prod_{k=1}^{d}\left(1-\mu_{ij}^k\right)^{\theta_k}}, \frac{\prod_{k=1}^{d}\left(\nu_{ij}^k\right)^{\theta_k}}{\prod_{k}^{d}\left(\nu_{ij}^k\right)^{\theta_k} + \prod_{k=1}^{d}\left(1-\nu_{ij}^k\right)^{\theta_k}} \right\rangle$$

Let $w_j^k = \left(\mu_j^k, \nu_j^k\right)$ be the weight of the criteria C_j given by the experts M_k and is defined from the operator introduced by Xia and Xu [78] as:

$$w_j = \left\langle \frac{\prod_{k=1}^{d}\left(\mu_j^k\right)^{\theta_k}}{\prod_{k=1}^{d}(\mu_j^k)^{\theta_k} + \prod_{k=1}^{d}\left(1-\mu_j^k\right)^{\theta_k}}, \frac{\prod_{k=1}^{d}\left(\nu_j^k\right)^{\theta_k}}{\prod_{k}^{d}\left(\nu_j^k\right)^{\theta_k} + \prod_{k=1}^{d}\left(1-\nu_j^k\right)^{\theta_k}} \right\rangle$$

where $w_j = \left(\mu_j, \nu_j\right)$ is an important j^{th} criterion weight.

In Boran et al. [79], for each criterion, the normalized subjective weights w_j^t can be calculated as:

$$w_j^t = \frac{\left(\mu_j + \pi_j\left(\frac{\mu_j}{1-\pi_j}\right)\right)}{\sum_{j=1}^{n}\left(\mu_j + \pi_j\left(\frac{\mu_j}{1-\pi_j}\right)\right)}$$

The criteria's objective weight (OW) has been described by Xu and Hu [80] as well as Chen and Li [81], which have been proposed by Xia and Xu [78], Zavadskas and Podvezko [82], and Zavadskas et al. [83] is evaluated as:

$$w_j^q = \frac{1-E_j(f)}{\sum_{j=1}^{n}\left(1-E_j(f)\right)} \text{ with } 0 \le w_j^q \le 1 \text{ and } \sum_{j=1}^{n} w_j^q = 1$$

where

$$E_j(f) = -\frac{1}{m\ln 2}\sum_{i=1}^{m}\left[\begin{array}{l}\mu_{ij}\ln\mu_{ij} + \nu_{ij}\ln\nu_{ij} - \left(\mu_{ij}+\nu_{ij}\right)\ln\left(\mu_{ij}+\nu_{ij}\right) - \\ \left(1-\left(\mu_{ij}+\nu_{ij}\right)\right)\ln 2\end{array}\right]$$

The positive and negative ideal solutions under IF are $\psi_j^* = \left(\mu_j^*, \nu_j^*\right)$ and $\psi_j^- = \left(\mu_j^-, \nu_j^-\right)$, respectively, of all criteria is defined as:

$$\psi_j^* = \left\{\begin{array}{l}\max \mathrm{r}_{ij}, \text{for benefit criteria} \\ \min \mathrm{r}_{ij}, \text{for cost criteria}\end{array}\right\}$$

$$\psi_j^- = \left\{\begin{array}{l}\max \mathrm{r}_{ij}, \text{for benefit criteria} \\ \min \mathrm{r}_{ij}, \text{for cost criteria}\end{array}\right\}$$

The normalized IF differences $\overline{\Omega}_{ij}$ by using the expression are proposed by Xu and Hu [80] as:

$$\bar{\Omega}_{ij} = \frac{\Omega\left(\Psi_j^*, r_{ij}\right)}{\Omega\left(\Psi_j^*, \Psi_j^-\right)}$$

where

$$\Omega\left(\Psi_j^*, r_{ij}\right) = \frac{\left|\mu_j^* - \mu_{ij}\right| + \left|\nu_j^* - \nu_{ij}\right|}{4} + \frac{\max\left(\left|\mu_j^* - \mu_{ij}\right|, \left|\nu_j^* - \nu_{ij}\right|\right)}{2}$$

$$\Omega\left(\Psi_j^*, \Psi_j^-\right) = \frac{\left|\mu_j^* - \mu_j^-\right| + \left|\nu_j^* - \nu_j^-\right|}{2} + \frac{\max\left(\left|\mu_j^* - \mu_j^-\right|, \left|\nu_j^* - \nu_j^-\right|\right)}{2}$$

Expressions: R_i, C_i, and Q_i are defined as:

$$C_i = \sum_{j=1}^{n}\left[\phi\ w_j^q + (1-\phi)w_j^q\right]\overline{\Omega}_{ij} = \sum_{j=1}^{n} w_j^l\ \overline{\Omega}_{ij}$$

$$R_i = \max\left(\mathrm{w}_j^l \overline{\Omega}_{ij}\right)$$

$$Q_i = \nu\frac{S_i - S^*}{S^- - S^*} + (1-\nu)\frac{R_i - R^*}{R^- - R^*}$$

where
C_i is the normalized and weighted Manhattan distance measure.
R_i is the normalized and weighted Chebyshev distance measure.
Q_i is the compromise solution.
$w_j^l = \phi w_j^t + (1-\phi)w_j^q$ is the criteria's combination weights and $\phi \in [0, 1]$ has been considered for easy computations.

$$Q_i = \nu\frac{C_i - C^*}{C^- - C^*} + (1-\nu)\frac{R_i - R^*}{R^- - R^*} \text{ with}$$

$$C^* = \min_i C_i\ ;\ C^- = \max_i C_i;\ R^* = \min_i R_i;\ R^- = \max_i R_i$$

Taking $\nu = 0.5$.

The weights for the individual regret and strategy of maximum group utility are $1 - \nu$ and ν, respectively.

Acceptable Conditions:

$$QG^{(2)} - QG^{(1)} \ge \frac{1}{(m-1)} \quad (1)$$

where $G^{(2)}$ alternative with second place with respect to Q.

Acceptable Stability

1) When $\nu > 0.5$, voting is by majority rule.
2) When $\nu \approx 0.5$, voting is by consensus.
3) When $\nu < 0.5$, voting is by veto.

Figure 1
Symptoms of vector-borne diseases

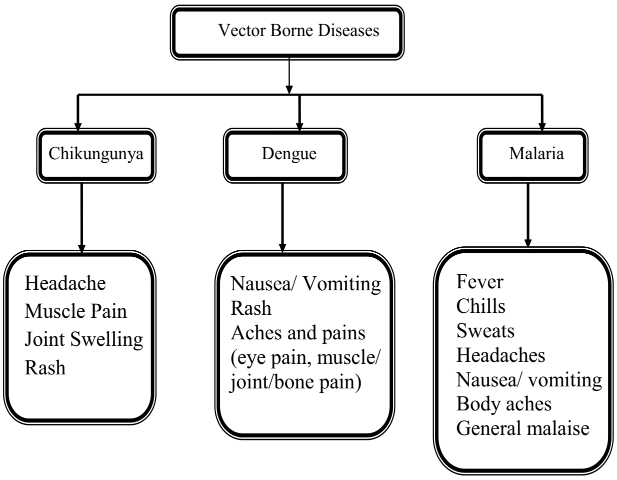
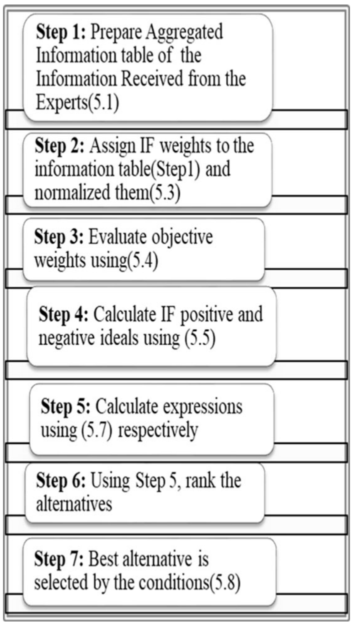


Figure 2
Steps of VIKOR method



If the stability conditions from 1) to 3) are not satisfied, then

1) If Equation (1) is not satisfied, then alternatives $G^{(1)}$ and $G^{(2)}$ have been employed.
2) If Equation (1) is not satisfied, then alternatives can be calculated using $QG^{(M)} - QG^{(1)} < \frac{1}{m-1}$ with highest M.

6. Symptoms of VBDs

According to the Centers for Disease Control and Prevention, the symptoms of VBDs are represented in Figure 6.

7. Steps of VIKOR Method

In this process, the initial information is given in the form of related linguistic terms with assigned IFNs. These criteria subjective loads are assessed by some expert by means of linguistic terms appeared in the information, collected from the source mentioned in the literature. The decision-making performed by means of the proposed IF VIKOR technique to rank the diseases is given in Figures 1 and 2.

8. Evaluation of Case Study

IF-VIKOR technique for the diagnosis of VBDs has been demonstrated in this section. For this purpose, data of four patients have been collected from government hospital situated in Delhi region by the help of three medical experts $\{M_1, M_2 M_3\}$, given in Appendix 1.

Let $\{p10001, p10002, p10003, p10004\}$ be the suspected patients in a hospital, which may have any of the given VBD. The medical experts examine the patients through symptoms and related tests and propose the treatment for a suitable disease. Let $\{G^c, G^d, G^m\}$ be the given VBDs as chikungunya, dengue, and malaria, respectively, known as alternatives. Let $\{S_1, \ldots.., S_7\}$ be the set of common associated symptoms of the VBDs as fever, joint pain, chills and rigors, body rash, retro orbital headache, muscle/ body pain, and vomiting/nausea, respectively.

In the process of diagnosis of diseases, accompanying weights have been allocated to three medicinal specialists: $\theta_1 = 0.20$, $\theta_2 = 0.35$, $\theta_3 = 0.45$, respectively. The weights assigned to each expert are on the basis of their background and expertise in the clinical diagnosis of diseases.

The computational procedure for the diagnosis of diseases on the basis of given data has been discussed in Tables 2, 3, 4, and 5, and decision matrix against each linguistic variable is defined as per the assigned IFN (Table 1). IFE value of each criteria has been assigned using OW method (5.4) which is given in Table 6. IF positive and negative ideal solution has been calculated in Tables 7 and 8. Normalized weights and IF differences, respectively, are given in Table 9. Ranking against each alternative is given in Table 11 using the calculations of Table 10.

On the basis of Q values, the ranking of diseases against each by VIKOR method is given in Table 11.

On the basis of Q values, given in Table 10, the graph has been plotted in Figure 8.

Lesser value of Q gives the estimation of the suitable disease.

9. Result and Discussion

The ranking of diseases is given in Figure 3. Based on the proposed method, patient p10001 has been diagnosed with

Table 1
Criteria weights associated with the linguistic terms

Linguistic terms	Unsatisfied (US)	Satisfied (Sa)	Somehow satisfied (SS)	Very strongly satisfied (VSS)
IFN (μ_j, ν_j)	(0.05, 0.90)	(0.50, 0.50)	(0.80, 0.10)	(0.90, 0.05)

Table 2
Collective information of symptoms against identified diseases for patient p10001

Diseases	S_1	S_2	S_3	S_4	S_5	S_6	S_7
G^c	(0.85,0.09)	(0.17,0.77)	(0.17,0.77)	(0.17,0.77)	(0.85,0.07)	(0.60,0.29)	(0.51,0.37)
G^d	(0.50,0.50)	(0.17,0.77)	(0.05,0.90)	(0.05,0.90)	(0.05,0.90)	(0.81,0.11)	(0.36,0.61)
G^m	(0.86,.07)	(0.05,.90)	(0.86,0.07)	(0.86,0.07)	(0.88,0.06)	(0.50,0.50)	(0.51,0.37)
w_j	(0.80,0.10)	(0.50,0.90)	(0.90,.05)	(0.05,0.90)	(0.05,.90)	(0.26,0.68)	(0.5087,0.366)

Table 3
Collective information of symptoms against identified diseases for patient p10002

Diseases	S_1	S_2	S_3	S_4	S_5	S_6	S_7
G^c	(0.82,0.09)	(0.86,0.07)	(0.09,0.85)	(0.90,0.05)	(0.05,0.90)	(0.80,0.10)	(0.50,0.50)
G^d	(0.65,0.27)	(0.21,0.73)	(0.21,0.73)	(0.65,0.27)	(0.65,0.27)	(0.50,0.50)	(0.80,0.10)
G^m	(0.17,0.77)	(0.17,0.77)	(0.40,0.45)	(0.09,0.85)	(0.17,0.77)	(0.05,0.90)	(0.09,0.85)
w_j	(0.80,0.10)	(0.90,0.05)	(0.05,0.90)	(0.71,0.19)	(0.05,0.65)	(0.34,0.77)	(0.1653,0.77)

Table 4
Collective information of symptoms against identified diseases for patient p10003

Diseases	S_1	S_2	S_3	S_4	S_5	S_6	S_7
G^c	(0.85,0.09)	(0.17,0.77)	(0.17,0.77)	(0.17,0.77)	(0.85,0.07)	(0.60,0.29)	(0.51,0.37)
G^d	(0.50,0.50)	(0.17,0.77)	(0.05,0.90)	(0.05,0.90)	(0.05,0.90)	(0.81,0.11)	(0.36,0.61)
G^m	(0.86,.07)	(0.05,0.90)	(0.86,0.07)	(0.86,0.07)	(0.88,0.06)	(0.50,0.50)	(0.51,0.37)
w_j	(0.80,0.10)	(0.90,0.05)	(0.05,0.9)	(0.71,0.19)	(0.05,0.90)	(0.34,0.77)	(0.16,0.77)

Table 5
Collective information of symptoms against identified diseases for patient p10004

Diseases	S_1	S_2	S_3	S_4	S_5	S_6	S_7
G^c	(0.71,0.19)	(0.74,0.19)	(0.05,0.9)	(0.84,0.08)	(0.5,0.5)	(0.21,0.73)	(0.05,0.9)
G^d	(0.87,0.06)	(0.85,0.07)	(0.9,0.05)	(0.86,0.07)	(0.86,0.07)	(0.85,0.09)	(0.27,0.55)
G^m	(0.65,0.27)	(0.17,0.77)	(0.05,0.9)	(0.05,0.9)	(0.05,0.9)	(0.13,0.81)	(0.5,0.5)
w_j	(0.90,0.05)	(0.80,0.10)	(0.05,0.90)	(0.80,0.10)	(0.90,0.05)	(0.80,0.10)	(0.17,0.90)

Table 6
OWs and the evaluated IFE values of the associated symptoms

Weights	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Patient: p10001							
E_i	0.6388	0.5782	0.4873	0.4873	0.3839	0.8288	0.9736
w_j^q	0.1378	0.1609	0.1955	0.1955	0.2350	0.0653	0.0101
Patient: p10002							
E_i	0.6993	0.6366	0.7554	0.5680	0.6390	0.6285	0.6803
w_j^q	0.1257	0.1519	0.1022	0.1805	0.1509	0.1552	0.1336
Patient: p10003							
E_i	0.6812	0.6292	0.3326	0.4110	0.5870	0.6245	0.7541
w_j^q	0.1070	0.1244	0.2239	0.1976	0.1386	0.1260	0.0825
Patient: p10004							
E_i	0.6388	0.5782	0.4873	0.4873	0.3839	0.8288	0.9736
w_j^q	0.1378	0.1609	0.1955	0.1955	0.2350	0.0653	0.0101

Note: The IF positive ideal solution of all criteria ratings for each patient is as given in Table 7.

Table 7
IF positive ideal solution for each patient

Patient	f_1^+	f_2^+	f_3^+	f_4^+	f_5^+	f_6^+	f_7^+
p10001	(0.86,0.07)	(0.17,0.77)	(0.86,0.07)	(0.86,0.07)	(0.88,0.06)	(0.81,0.011)	(0.36,0.61)
p10002	(0.82,0.09)	(0.86,0.07)	(0.40,0.45)	(0.90,0.05)	(0.65,0.27)	(0.80,0.10)	(0.09,0.85)
p10003	(0.87,0.06)	(0.85,0.07)	(0.90,0.05)	(0.86,0.07)	(0.86,0.07)	(0.85,0.09)	(0.05,0.90)
p10004	(0.82,0.09)	(0.86,0.07)	(0.80,0.12)	(0.87,0.06)	(0.65,0.27)	(0.68,0.023)	(0.17,0.77)

Note: The IF negative ideal solution of all criteria ratings for each patient is as given in Table 8.

Table 8
IF negative ideal solution for each patient

Patient	f_1^-	f_2^-	f_3^-	f_4^-	f_5^-	f_6^-	f_7^-
p10001	(0.5,0.5)	(0.05,0.9)	(0.05,0.9)	(0.05,0.9)	(0.05,0.9)	(0.5,0.5)	(0.51,0.37)
p10002	(0.17,0.77)	(0.17,0.77)	(0.09,0.85)	(0.09,0.85)	(0.05,0.90)	(0.05,0.90)	(0.80,0.10)
p10003	(0.65,0.27)	(0.17,0.77)	(0.05,0.90)	(0.05,0.90)	(0.05,0.90)	(0.13,0.81)	(0.50,0.50)
p10004	(0.21,0.73)	(0.36,0.61)	(.17,0.77)	(.09,0.85)	(.13,0.81)	(0.21,0.73)	(0.65,0.21)

Table 9
Normalized SWs for patients

Diseases	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Patient: p10001							
G^c	0.0424	0	0.8455	0.8455	0.0299	0.5473	1
G^d	1	0	1	1	1	0	0
G^m	0	1	0	0	0	1	1
w_j^t	0.2815	0.1131	0.30	0.0167	0.0167	0.0880	0.1841
Patient: p10002							
G^c	0	0	1	0	1	0	0.5338
G^d	0.2639	0.9427	0.6821	0.3003	0	0.4762	1
G^m	1	1	0	1	0.7952	1	0
w_j^t	0.2765	0.2946	0.0164	0.2445	0.0164	0.0967	0.0550
Patient: p10003							
G^c	0.7011	0.1691	1	0.0212	0.50	0.8889	0
G^d	0	0	0	0	0	0	0.7257
G^m	1	1	1	1	1	1	1
w_j^t	0.1986	0.1864	0.0110	0.1864	0.1986	0.1864	0.0325
Patient: p10004							
G^c	0.0424	0	0.8455	0.8455	0.0299	0.5473	1
G^d	1	0	1	1	1	0	0
G^m	0	1	0	0	0	1	1
w_j^t	0.2765	0.2946	0.0164	0.2445	0.0164	0.0967	0.0550

Note: The S, R, and Q values for each disease against each patient are given in Table 10.

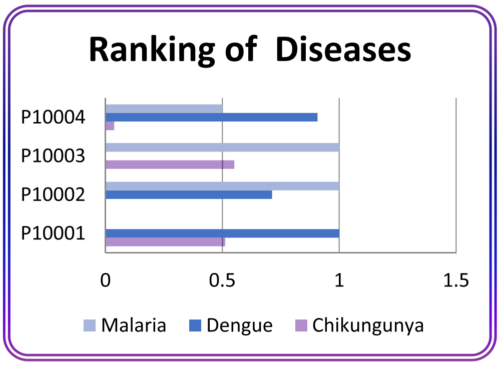
Table 10
S, R, and Q values for the diseases of each patient

Indexes	G^c	G^d	G^m
Patient: p10001			
S	0.4509	0.6893	0.3107
R	0.2095	0.2478	0.1370
Q	0.5123	1	0
Patient: p10002			
S	0.1932	0.5221	0.8293
R	0.7126	0.2105	0.2233
Q	0	0.7126	1
Patient: p10003			
S	0.4781	0.0417	1
R	0.1388	0.0417	0.1920
Q	0.5508	0	1
Patient: p10004			
S	0.3650	0.6587	0.3413
R	0.1860	0.2200	0.2277
Q	0.0373	0.9074	0.50

Table 11
Ranking of diseases by VIKOR method

Patient	Ranking by VIKOR	Disease
p10001	$G^m \succ G^c \succ G^d$	Malaria
p10002	$G^c \succ G^d \succ G^m$	Chikungunya
p10003	$G^d \succ G^c \succ G^m$	Dengue
p10004	$G^c \succ G^m \succ G^d$	Chikungunya

Figure 3
Ranking of diseases



malaria, patient p10003 has been diagnosed with dengue, and patients p10002 and p10004 have been diagnosed with chikungunya. The given patients under patient ID (p10001–p10004) have been diagnosed with the same disease by the doctors and the proposed method.

10. Conclusion

VIKOR approach under IF environment has been used for the diagnosis of VBDs. Data of four patients under patient ID p10001–p10004 have been collected from the health center situated in Delhi region given in Appendix 1. Originally, the data given in linguistic variables have been described in the prescribed IFNs. The collective assessment of expert's opinion by using the proposed method provides a solution for the diagnosis of diseases and their ranking. The method is very much effective for initial guess and to start the suitable treatment for the diagnosed disease.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that he has no conflicts of interest to this work.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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Appendix 1. Representation of Collected Data

The data collected from government hospital situated in Delhi region are given in Tables A2–A6. The linguistic terms used in the dataset are given in Table A1.

Table A1
Linguistic terms used in the data collection

Linguistic terms	Unsatisfied (US)	Satisfied (Sa)	Somehow satisfied (SS)	Very strongly satisfied (VSS)

Table A2
Medical expert's opinion of the associated symptoms of the diseases

	Chikungunya			Dengue			Malaria		
Symptoms	M1	M2	M3	M1	M2	M3	M1	M2	M3
S1	SS	SS	SS	VSS	VSS	VSS	SS	SS	SS
S2	VSS	VSS	VSS	SS	SS	SS	US	US	US
S3	US	US	US	US	US	US	VSS	VSS	VSS
S4	SS	Sa	SS	SS	SS	SS	US	US	US
S5	US	US	US	VSS	VSS	VSS	US	US	US
S6	US	US	US	SS	SS	SS	Sa	US	Sa
S7	US	US	Sa	US	US	Sa	US	Sa	SS

Table A3
Post-examination medical expert's opinion for the patient "p10001"

Symptoms (S)	Medical expert (M)	Diseases		
		Chikungunya	Dengue	Malaria
S1	M1	Sa	Sa	VSS
	M2	US	Sa	VSS
	M3	US	US	SS
S2	M1	US	US	US
	M2	US	Sa	US
	M3	Sa	Sa	US
S3	M1	US	US	VSS
	M2	US	US	VSS
	M3	Sa	US	SS
S4	M1	US	US	VSS
	M2	US	US	VSS
	M3	Sa	US	VSS
S5	M1	SS	US	SS
	M2	SS	US	SS
	M3	VSS	Sa	VSS
S6	M1	US	Sa	SS
	M2	Sa	SS	Sa
	M3	VSS	VSS	Sa
S7	M1	US	US	US
	M2	SS	Sa	Sa
	M3	SS	Sa	SS

Table A4
Post-examination medical expert's opinion patient for the "p10002"

Symptoms (S)	Medical expert (D)	Diseases		
		Chikungunya	Dengue	Malaria
S1	M1	VSS	Sa	US
	M2	SS	US	US
	M3	SS	SS	Sa
S2	M1	VSS	Sa	US
	M2	VSS	Sa	US
	M3	SS	US	Sa
S3	M1	Sa	Sa	Sa
	M2	US	Sa	US
	M3	US	US	SS
S4	M1	VSS	Sa	Sa
	M2	VSS	Sa	US
	M3	VSS	SS	US
S5	M1	US	Sa	US
	M2	US	Sa	US
	M3	US	SS	Sa
S6	M1	SS	Sa	US
	M2	SS	Sa	US
	M3	SS	Sa	US
S7	M1	Sa	SS	Sa
	M2	Sa	SS	US
	M3	US	SS	US

Table A5
Post-examination medical expert's opinion for the patient "p10003"

Symptoms (S)	Medical expert (D)	Diseases: Chikungunya	Dengue	Malaria
S1	M1	SS	VSS	Sa
	M2	Sa	SS	Sa
	M3	SS	VSS	SS
S2	M1	SS	SS	US
	M2	VSS	SS	US
	M3	Sa	VSS	Sa
S3	M1	US	VSS	US
	M2	US	VSS	US
	M3	US	VSS	US
S4	M1	SS	VSS	US
	M2	VSS	VSS	US
	M3	SS	SS	US
S5	M1	Sa	VSS	US
	M2	Sa	VSS	US
	M3	Sa	SS	US
S6	M1	Sa	Sa	US
	M2	Sa	VSS	Sa
	M3	US	VSS	US
S7	M1	US	Sa	Sa
	M2	US	Sa	Sa
	M3	US	SS	Sa

Table A6
Post-examination medical expert's opinion for the patient "p10004"

Symptoms (S)	Medical expert (D)	Diseases: Chikungunya	Dengue	Malaria
S1	M1	VSS	Sa	SS
	M2	SS	Sa	US
	M3	SS	US	Sa
S2	M1	VSS	US	US
	M2	VSS	Sa	Sa
	M3	Sa	Sa	Sa
S3	M1	VSS	US	US
	M2	SS	SS	Sa
	M3	VSS	Sa	US
S4	M1	SS	US	Sa
	M2	SS	US	Sa
	M3	VSS	US	Sa
S5	M1	Sa	US	US
	M2	Sa	US	Sa
	M3	SS	Sa	Sa
S6	M1	SS	Sa	Sa
	M2	SS	Sa	Sa
	M3	Sa	SS	US
S7	M1	Sa	Sa	US
	M2	Sa	Sa	US
	M3	SS	US	Sa