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Predicting Customer Satisfaction based on Neutrosophic sets: Applied on mobile food ordering application.

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Abstract: Customers' satisfaction prediction is a vital process for all business organizations to draw new customers and maintain existing customers. One of the most efficient methods to predict customers' satisfaction is classifying customers' feedback. In the real world, customer's feedback is ambiguous, confusing and inconsistent. This option can be stated in neutrosophic logic as indeterminacy membership, associated with truth and falsity membership. In this study, a classification model based on neutrosophic sets to handle the inconsistency of customer responses is presented. Also, significant factors that impact customers' satisfaction are defined. In order to show the procedures and the application of the proposed method, a case study to determine the customers' satisfaction while using food order application (Talabat) in Egypt is presented. A comparison between the classical classification models and the proposed model based on neutrosophic sets is presented. The experimental results indicate that the proposed classifying model achieved accuracy results around 95.36% to 99.95%, higher than the classical one that achieve around 90.3% to 93.99%. Next, a sensitivity analysis is performed for reliability validation as to determine the most factors that affect customers' satisfaction.

Keywords: Food Ordering Applications, Neutrosophic Logic, Neutrosophic set, Classification, Neutrosophic Classifier.

1. Introduction

Nowadays, customer satisfaction plays an important role in improving and developing any organization. Customer satisfaction is a crucial issue that can be considered one of the organization's assets, as customer satisfaction, in turn, affects the formulation of the organization's strategies and promotional campaigns and, thus, the success or failure of the organization [1, 2]. Moreover, obtaining and analyzing customer reviews in the restaurant sector is an extremely difficult issue. Valuable customer feedback can be challenging to establish as it includes variation in customer interpretation of their experiences, and reliability of survey results. On the other hand, the progress that has occurred in e-commerce and then in online applications has helped influence how to collect customer reviews in a more impartial manner [3]. Hence, online food ordering applications were able to obtain customer reviews about different restaurants in an unbiased manner [2, 4].

Recently, online food ordering applications have been widely used in different restaurant sectors to provide their services to customers. However, there are significant issues regarding the effect of applying food ordering applications on customer satisfaction [4]. Egyptian restaurants and stores started to consider mobile applications as a new mechanism to attract new customers and keep current customers' satisfaction. For example, more than 3800 Egyptian restaurants and and stores joined the Talabat application to take orders from customers in 2023 [5].

Customers, by using food ordering applications, can order their food at times and locations desired by to them. These applications provide customers with up-to-date information about the restaurant and store options [6, 7]. Also, it gives customers the ability to see their order progress through all its stages. Food ordering applications help customers and restaurants overcome difficulties such as misunderstandings, late deliveries, or handling complaints [8, 9]. Customers' opinions towards food ordering applications have been a significant issue recognized by a number of researchers. It was found that customers' satisfaction with food ordering applications is largely affected by the level of trust, product quality, and significant differences in the customers' points of view of such applications [10–12].

On the other hand, evaluating customer reviews about restaurants is considered one of the most complicated issues because it is vague, imprecise, and indeterminate. Generally, the customer expresses his opinion by selecting the most likely choice from: very good, good, normal, bad, or very bad. Many studies presented various theories to handle human thinking uncertainty [13]. Professor Zadeh introduced fuzzy logic, which considers the degree of the membership of elements in a set, in 1965 [14]. In 1975, Zadeh introduced type 2 fuzzy logic, in which membership degrees themselves are fuzzy [15]. Attanssov presented intuitionistic fuzzy logic as an extension of the standard fuzzy sets in 1983 [16]. Fuzzy set theory, intuitionistic fuzzy sets, and neutrosophy theory have been proposed to deal with uncertain, indeterminate, inaccurate, and vague data in everyday life problems such as decision-making, engineering, computer science, and finance [17]. Fuzzy logic can only express vagueness when information is naturally graded. However, type-2 and intuitionistic fuzzy logic, proposed by Attanssov as an extension of normal fuzzy sets, may describe vagueness and imprecision using a range of membership values. Previous study suggests that dealing with ambiguity and contradictory data is crucial for improving customer feedback accuracy [18].

The four main categories of uncertainty data are vagueness, impreciseness, inconsistency, and ambiguity, an example of vague information would be the following sentence: "The food quality is very good"; the Fuzzy set can handle vagueness as a type of uncertainty. An example of imprecise information would be the following sentence: "The food is neither good nor bad"; the Intuitionistic fuzzy set can represent imprecision. A statement of ambiguous information could be: "The food quality is typically about 75%." Inconsistent information is represented by the following sentence: "The probability that food quality is good is 60%" and that doesn't mean that the probability of the food quality is bad is 40% given that there may be unknown hidden reasons; All of the previously mentioned uncertainties may be handled by a neutrosophic set. [19, 20].

Smarandache introduced neutrosophic logic to handle inconsistent and imprecise information to express the percentage of unknown parameters [19]. Neutrosophic logic handles the indeterminacy of customers' responses better and simulates human thinking [20]. Therefore, neutrosophic logic has the potential to simulate human thought processes, resolve paradoxes that are both true contrasting to each other, and be applied to real-world issues. Hence, the researchers suppose that the outcome of evaluating the customer reviews may enhance the classification results after using neutrosophic logic. As a result of the above discussion, there are no previous studies that handle impreciseness and ambiguity in customers' responses for better classification accuracy. An example of vagueness, impreciseness, and ambiguity in customers' response choices is excellent, very good, good, normal, bad, or very bad [13]. The undecided response is a choice by the customer who is unsure. A neutral set can handle all the above uncertainties. Consequently, neutrosophic logic is a proposed approach for customer satisfaction classification to deal with uncertainty [19, 20]. Moreover, no research has investigated the relationship between customer satisfaction and the combination of order packaging, value for money, delivery time, and quality of the food in Egypt.

A research gap exists in related work, since no studies have been conducted to investigate the association between customer satisafaction and the combination of order packing, value for money, delivery time, and quality of food. In addition, no previous study addressed impreciseness and ambiguity in customer replies for better classification accuracy. Excellent, very good, good, normal, awful, or extremely bad are examples of vagueness, impreciseness, and ambiguity in customer responses [11]. The customer who is unsure may choose the undecided response. A neutral set can deal with all of the aforementioned uncertainties. As a result, neutrosophic logic is a recommended way to cope with uncertainty in customer satisfaction classification [1, 16].

In this study, a proposed model based on a neutrosophic set is presented. The main novelties of this research are shown in the following points:

- Obtaining and handling vagueness, impreciseness, and ambiguity customers' responses from Talabat ordering application by utilizing the neutrosophic set.
- Presenting a classification model to determine the customer satisfaction class as satisfied, neutral, and unsatisfied based on neutrosophic sets.
- Discovering the importance of neutrosophic sets by introducing a comparison between the classical classification models and the proposed model based on neutrosophic sets.
- Defining which attributes have the most effect on customer satisfaction in mobile food ordering applications.
- Following that, a sensitivity analysis is performed to validate the reliability.

The paper is organized as follows: section 2 discusses the related work; Section 3 explains the research methodology; Section 4 presents the applied experiment; Section 5 presents the discussion and results; Section 6 presents the conclusion and future work.

2. Related work

Customer satisfaction has become an important factor as the market has changed from a vendor-driven market to a customer-driven one [21]. Customer satisfaction answers questions related to

present customers and potential customers which contributes to higher profitability [20]. Customers' reviews play a critical role in the selection process to evaluate customers' satisfaction and dissatisfaction [22]. Analyzing the customer's reviews is essential for improving service quality to gain a competitive advantage [23,24].

Food delivery has become a rising business that has extended in many regions. Previous studies concern the factors affecting food ordering application customers' satisfaction while ordering food online. [4, 5]. A study was conducted to investigate the interest to use food ordering applications through the evaluation of customer satisfaction, food quality, and service quality [25]. Saad AT presented a study to explore customer behavior, the study concerns on the services that bring food from the restaurants, not the product. The survey results were analyzed using MS–Excel and SPSS, it was concluded that delivery time, service quality, price, and condition of food delivered are the most important factors affecting the success of online food delivery [26]. Dirsehan, T., & Cankat, E. found that food ordering application plays a decisive function in developing restaurants' satisfaction and loyalty. Theuiy conducted a survey including filtering, customers' attitudes and customers' behavior questions [27].

Another study collected customer opinions using survey to examine the effect of ease of use. The study concluded that customer trust was affected by perceived usefulness and perceived ease of use positively. It was shown that application's ease of use enhances continuous usage [28]. Tandon investigated factors that contribute to forming customers' loyalty in the context of food delivery application. The results indicated that food ordering application has changed the food delivery industry [29]. The customers' confidence in food ordering application was examined including the role of technology acceptance model, mobile service quality, and privacy in promoting customers' confidence. The study helped owners of food ordering applications by providing product design and service strategy to enhance their competitive advantage [30].

From previous studies, it can be concluded that many researchers have conducted custom surveys to investigate customer satisfaction for food delivery applications. The survey method has limitations due to human discourage, difference, and unawareness [31]. Survey results may be inaccurate as they may be a collection of overall customer opinions on the most important factors affecting their satisfaction [32].

To address this gap, order review mining takes place to gain more precise customer information through the application. There are only limited studies on customers' reviews that use mining to explore the factors reflecting customer satisfaction [33-34]. Therefore, there is a need to conclude meaningful implications by analyzing customer reviews and exploring which attributes affected customer satisfaction in mobile food ordering application. Collecting reviews using mobile food ordering application is more accurate than the general survey because the customer gives feedback immediately after the purchase. On the other hand, not all previous research has been applied in Egypt.

Customers' reviews are mostly collected using a scaling responses choice such as very good, good, normal, bad, very bad, or totally disagree, disagree, neutral, agree and totally agree. The neutral or undecided choice is an option by the customer who is unsure [11]. In real world, customers' responses are not strict, but it is vague, imprecise, ambiguous and inconsistent information. Neutrosophic logic can express this option by indeterminacy membership with truth and falsity membership [35].

Neutrosophic logic is an extension of fuzzy logic which is a better choice to handle indeterminacy that expresses the degree of unknown parameters. It is described by triple values t, i, and f where t is the grade of truth, f is the grade of false and i is the grade of indeterminacy [36]. Neutrosophic logic expresses inconsistency and contradictions found in human thinking. Also, it helps in the decision-making process in the case of information conflict due to human observation from the surrounding world [37].

Neutrosophic set can express customers' responses with three membership functions and then be analyzed based on the weights appointed to each response in the questionnaire. From this, the customer segment can be determined, and this can be used by the decision-makers to modify its strategy [38]. The indeterminacy degree gives the possibility to define the unrecognized information in the model. Therefore, decision-makers by handling uncertain information can make more reasonable decisions [39, 40]. Lately, neutrosophic set has been widely studied to solve different problems such as crowd management [41], obstacles analysis [42], energy resources management [43], and inventory control model [44] as ambiguous and partial data may be handled by fuzzy sets and intuitionistic fuzzy set theories, not neutral data, which is typically present in real-world world. Smarandache first provided a concept of an NS from a philosophical point of view that is a component of neutrosophic to manage all sorts of ambiguity, including neutrality [45, 46]. The researchers note that a limited number of previous research used neutrosophic logic in determining customer satisfaction. Moreover, the previous research did not use the same methodology or dataset as the researchers used in this research [31-34, 47-50].

Classification is an important technique in data mining to put out data into similar groups depending on the data features. Most machine learning techniques are used to classify all possible inputs into defined classes. How to classify ambiguous data is a major research topic, which has been getting serious concern from researchers recently [51, 52].

Classification performed on imprecise and ambiguous is a question in many research [53]. For example, a study presented fuzzy logic techniques for infectious diseases identification such as hepatitis and tuberculosis. The evaluation indicators such as sensitivity and accuracy are employed [54]. Furthermore, intuitionistic fuzzy set has a powerful ability to address ambiguous data by assigning a lower degree to the outliers. Intuitionistic fuzzy classification is more powerful as compared to fuzzy classification as it deals with membership, hesitant level, and non-membership [55].

However, previous research that applied classification techniques based on fuzzy logic and intuitionistic fuzzy logic cannot handle vagueness, ambiguous, inconsistent, and imprecise data which found in nature [56-58]. In this paper, classification model based on neutrosophic set is presented to enhance the results of customers' feedback analysis. A comparison between the famous classification techniques such as naive Bayes, c4.5, random tree, and random forest, and the combined one with neutrosophic is presented. The proposed classification model has been implemented and experimental results showed that this system did quite better than classical techniques.

3. Materials and Methods

The proposed method is divided into three parts; the first part is to convert linguistic terms to neutrosophic sets. The second part is to apply classical and neutrosophic classification techniques to dataset, and the third part is to compare between results.

Neutrosophic set consists of three values true degree (t), indeterminate degree (i) and false degree (f) with no restriction on t, i, f, nor on their sum. For example, assume that (0.6, 0.3, and 0.5) is a neutrosophic set. This means that t=0.6 degrees, i=0.3 and f=0.5 [19, 20]. The linguistic terms excellent, good, fair, and poor are expressed by neutrosophic values. Linguistic terms and assigned neutrosophic set presented in Table 1 are defined as:

Table 1. Linguistic terms and the assigned neutrosophic set

Linguistic term	Neutrosophic set
Excellent	(1,0,0)
Very Good	(0.8, 0.15, 0.2)
Good	(0.7,0.25, 0.3)
Fair	(0.5,0.5,0.5)
Poor	(0.2, 0.7, 0.7)

Definition [38]: If A = (t, i, f) is a single-valued neutrosophic set, a score function is mapped into the single crisp output as S(A) follows: $S(A) = \frac{2+t-i-f}{3}$.

In this section the proposed classification model based on neutrosophic set is presented, Figure 1 describes the proposed model steps. In which, neutrosophication unit accepts linguistic term input which assigns the appropriate membership functions of inputs in true, false, and indeterminacy degrees. Then, the triple neutrosophic set is converted into a single crisp value to take the decision which is called de-neutrosophication. Let x= (TA, IA, FA) be a single value of neutrosophic set, then the proposed score function is defined as the following function: $S(A) = \frac{2+t-i-f}{3}$ [59].

Then classical classification techniques and the neutrosophic combined into one is applied on the dataset, the last step is validating the results by measuring the accuracies as Accuracy = True Positive +True Negative /True Positive + True Negative + False Positive + False Negative [60][61] and determine the critical factors that affects customers' satisfaction about restaurants.

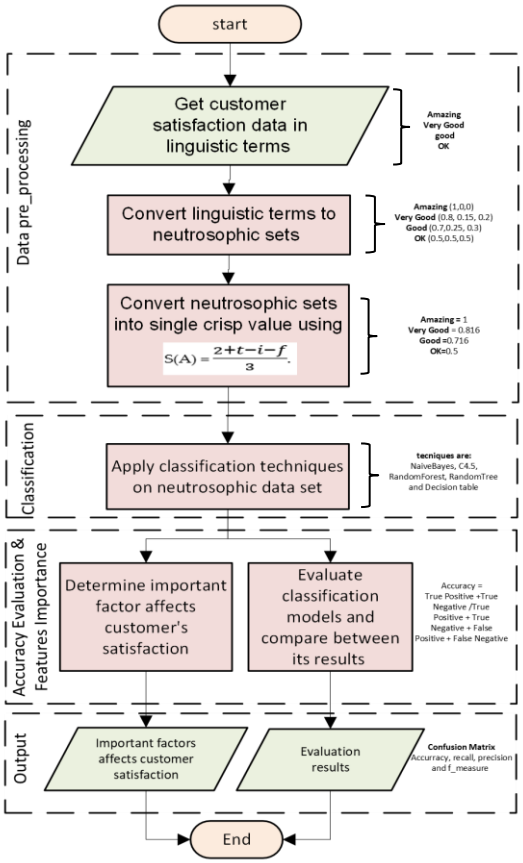

Figure 1. Classification Proposed Model based on Neutrosophic set Flowchart

4. Application

In this part, the proposed model is applied on customers scaling responses of food ordering applications called Talabat in Egypt.

4.1 The Dataset

The dataset characteristics are shown in Table 2. The dataset consists of 2330 reviews of different restaurant and stores that joined Talabat ordering food application in Egypt [62]. The dataset features are order packaging, value for money, delivery time and quality of food.

Table 2. Talabat dataset characteristics

Dataset characteristics	**Attribute characteristics**	**Associated tasks**
Multivariate	Categorical, integer, real	Classification
Number of instances	Number of attributes	Missing values?
2330	7	Yes

4.2 Data Preprocessing

There are many steps to prepare the data for use in a model. Data preprocessing includes removing the noise and handling missing data to obtain optimal results. Categorical variables needed to be encoded as satisfied, medium, and unsatisfied.

Table 3. Talabat dataset after preprocessing

ID	Reviews	OrderPackaging	ValueForMoney	DeliveryTime	QualityOfFood	Class
1	177	Good	Good	Good	Good	medium
6	564	Very Good	Very Good	Very Good	Very Good	Satisfied
10	40	Very Good	Very Good	Very Good	Very Good	Satisfied
12	334	Good	Good	Good	Good	medium
15	238	Very Good	Very Good	Very Good	Very Good	Satisfied
17	3117	Very Good	Very Good	Very Good	Very Good	Satisfied
20	79	Fair	Fair	Fair	Fair	Unsatisfied
22	3	Poor	Fair	Fair	Fair	Unsatisfied
25	7	Excellent	Excellent	Very good	Very good	Satisfied

4.3 Neutrosophic Set

In this phase; converting linguistic terms (dataset attributes: order packaging, value for money, delivery time and quality of food) into neutrosophic values with truth, falsity, and indeterminacy membership. Table 4 describes Talabat dataset after assigning neutrosophic set, while Table 5 shows Talabat dataset after applying de-neutrosophication process.

Table 4. A sample of Talabat dataset after assigning neutrosophic set

ID	Reviews	OrderPackaging	ValueForMoney	DeliveryTime	QualityOfFood	Class
1	177	(0.7,0.25, 0.3)	(0.7,0.25, 0.3)	(0.7,0.25, 0.3)	(0.7,0.25, 0.3)	medium
6	564	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	Satisfied
10	40	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	Satisfied
12	334	(0.7,0.25, 0.3)	(0.7,0.25, 0.3)	(0.7,0.25, 0.3)	(0.7,0.25, 0.3)	medium
15	238	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	Satisfied
17	3117	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	Satisfied
20	79	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	Unsatisfied
22	3	(0.2, 0.7, 0.7)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	(0.5,0.5,0.5)	Unsatisfied
25	7	(1,0,0)	(1,0,0)	(0.8, 0.15, 0.2)	(0.8, 0.15, 0.2)	Satisfied

Table 5. A sample of Talabat dataset after applying deneutrosophication process

D	Reviews	OrderPackaging	ValueForMoney	DeliveryTime	QualityOfFood	Class
1	177	0.716	0.716	0.716	0.716	medium
6	564	0.816	0.816	0.816	0.816	Satisfied
10	40	0.816	0.816	0.816	0.816	Satisfied
12	334	0.716	0.716	0.716	0.716	medium
15	238	0.816	0.816	0.816	0.816	Satisfied
17	3117	0.816	0.816	0.816	0.816	Satisfied
20	79	0.5	0.5	0.5	0.5	Unsatisfied
22	3	0.266	0.5	0.5	0.5	Unsatisfied

25	7	1	1	0.816	0.816	Satisfied

4.5 Classification

Weka (open-source software for knowledge discovery tasks) is used for dataset classifying after applying the proposed model based on neutrosophic sets using famous algorithms such as naive Bayes, c4.5, random tree, random forest, and decision table.*4.4 Accuracy Measurement*

Accuracy = True Positive +True Negative /True Positive + True Negative + False Positive + False Negative [56].

5. Discussion and Results

Classification results for each algorithm: naive Bayes, c4.5, random tree, random forest and decision table are showed in Table 5. All algorithms achieve accepted results 93.99%, 93.95%, 93.65%, 90.3% respectively but the neutrosophic classifying based models achieve higher accuracy results 95.36%, 99.95%, 99.95%, 99.78%. Then the feature selection is applied to the dataset to define important factors that affects customers' satisfaction while using food ordering application in Egypt which are, value for money, and quality of food. Table 6 shows the classification results using classical models and combined one with neutrosophic set.

Table 6. Classification Results for Different Classification Algorithm

	NaiveBayes		C4.5		RandomForest		RandomTree		Decision table	
	Classic Model	Proposed Model	Classic Model	Proposed Model	Classic Model	Proposed Model	Classic Model	Proposed Model	Classic Model	Proposed Model
Precision	0.940	0.954	0.938	1.000	0.940	1.000	0.928	0.998	0.936	1.000
Recall	0.940	0.954	0.975	1.000	0.968	1.000	0.929	0.999	0.979	1.000
F-measure	0.940	0.954	0.956	1.000	0.954	1.000	0.928	0.999	0.957	1.000

The classified algorithms naive bayes, c4.5, random tree, random forest and decision table were applied to measure confusion matrix TP rate, FP rate, precision, recall, F-measure and ROC area). Table 7 and 8 show the confusion matrix for Naive Bayes performance and proposed model based on neutrosophic sets respectively. Figures 2 and 3 show the comparison between correctly and incorrectly classified results in classical model and neutrosophic based model.

Table 7. Confusion matrix for Naive Bayes performance using classical model

Confusion Matrix for Naive Bayes Classifier performance using Classical Model			
classified as	**a**	**b**	**c**
a= medium	**660**	**98**	**0**
b=satisfied	**41**	**1531**	**0**
c=unsatisfied	**1**	**0**	**0**

Table 8. Confusion matrix for Naive Bayes performance after applying the neutrosophic based model

Confusion Matrix for Naive Bayes Classifier performance after applying the Neutrosophic based model			
classified as	**a**	**b**	**c**
a= medium	**692**	**66**	**0**
b=satisfied	**41**	**1531**	**0**

c=unsatisfied	**1**	**0**	**0**

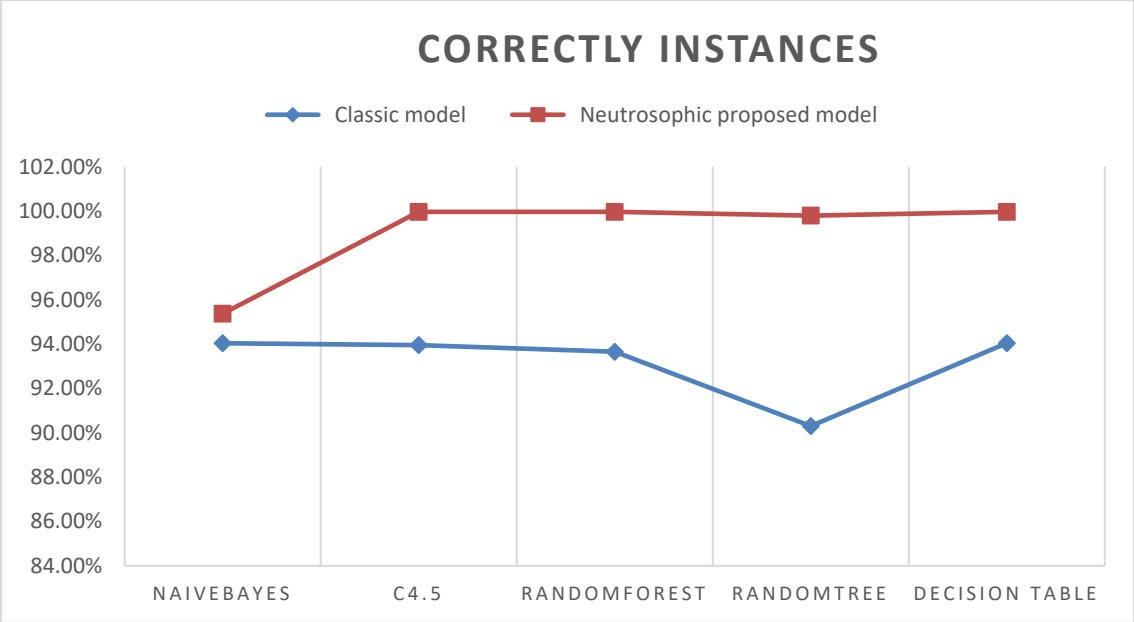

Figure 2. Correctly classified results for different classification algorithms.

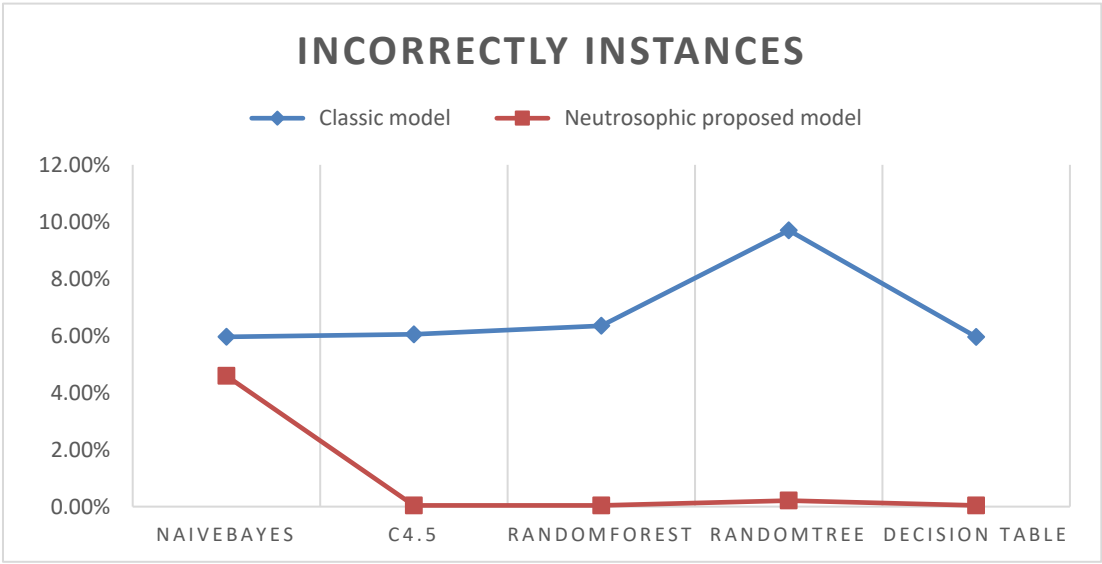

Figure 3. Incorrectly instances for different classification

6. Conclusion

Recently, studying the level of customer satisfaction has become one of the most critical issues facing researchers due to its importance in formulating corporate strategies, designing promotional campaigns, and identifying the most important factors that affect customer satisfaction. The emergence of online applications for ordering food and services has helped researchers facilitate the study of the level of customer satisfaction because these applications allow customers to evaluate food and services immediately after receiving them. Analyzing customers' reviews helps organizations understand overall customer satisfaction. Customers' reviews are mostly collected using scaling responses that have drawbacks like indeterminate information. These problems could

be handled when a neutrosophic set is used to express customers' responses in a realistic way, as it handles indeterminate information.

This paper introduced a classification model based on neutrosophic sets to handle the indeterminacy of customer reviews. The outcome indicates that the proposed model has an impact on classification outcome as accuracy increased. This due to the ability of neutrosophic sets to describe degrees of uncertainty that are difficult to be defined by fuzzy and intuitionistic fuzzy sets. For example, if a customer is asked for his opinion on a certain product or service, he may respond that he was satisfied by 80% unsatisfied by 30% and hesitated by 40%. This opinion may be handled adequately by neutrosophic logic, which has true, indeterminate, and false membership functions, depending on how absolute or conditional values are represented.

Based on the above, the researchers observed that the suggested classifying model produced accuracy values ranging from 95.36% to 99.95%, which is greater than the classical model's range of 90.3% to 93.99%. Additionally, the results of sensitive analysis approach in this paper after using the proposed model showed that two factors; value for money and food quality are among the most important factors that affect customer satisfaction while using the food ordering application (Talabat), so this can help the marketing department improve its work by creating promotional campaigns and improving communication with customers. Moreover, enhancing food quality and establishing prudent pricing strategies.

The research restrictions include that the results of this study are based on the data acquired from a single source, at a short period of time. Moreover, this study was carried out with data obtained from (Talabat) application in Egypt; the results of this research might vary from country to another. Finally, future research can be extended using more online applications over long period of time. Additionally, it can utilize neutrosophic multisets or neutrosophic soft sets.

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