Neutrosophic Monte Carlo Simulation Approach for Decision Making In Medical Diagnostic Process Under Uncertain Environment

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Abstract

This work emphasis on the basic notions regarding the Neutrosophic Fuzzy Sets (NFSs) with operations and their applicability in medical diagnostic process. In this manuscript, we developed neutrosophic fuzzy set-based Monte Carlo simulation technique for the decision making in medical diagnostic processin fuzzy environment. In this work, we managed the waiting time and idle time of the doctor during the treatment process of the patients. The various parameters are stated as linguistic variable in the form of NFSs. The developed neutrosophic Monte Carlo simulation technique (NMCST) is extended in the planning strategy of a doctor to treat the patient in a neutrosophic fuzzy environment. For the validation and authentication of the efficiency of the proposed NMCST, numerical computations are carried out with the examples of medical problems.

Keywords: Neutrosophic Fuzzy Sets (NFSs); Monte Carlo Simulation; Neutrosophic Fuzzy Set-based Monte Carlo Simulation Technique (NMCST); Medical Diagnostic Process

1. Introduction

Uncertainty is a common thing in every field of the life. It results from a loss of control over a certain event and can be observed in any area of life (for example, in any laboratory experiment, any sport, Medical, War, etc.). Generally, it is perceived that uncertainty can cause only havoc for the systems having only solution is right decision making in uncertain situations. During Second World War, Neumann and Ulamdeveloped the Monte Carlo simulation technique to tackle the decision making in ambiguous situations. This method is also known as Monte Carlo simulation method. It is a procedure for evaluate a variable based on one or more random factors. It is used in various fields such as marketing estimation, radiation therapy etc. Concato and Feinstein [1] analyzed that the Monte Carlo simulation offer attractive methods for clinical investigators to use in solving various problems. Abbas et al. [2] studied various simulation models for recruitment of patients in clinical trials with respect to the continuous as well as discrete time assumptions. It was found that continuous time simulation can reduce the duration of patient recruitment.Many researchers continued this concept in research of this field.Young-Jin Kim [3] pointed out that fuzzy Monte Carlo simulation is an important tool for reducing the uncertainty and global sensitivity analysis in any field. Sarrut et al. [4] studied the use of artificial intelligence approach in Monte Carlo simulation in various medical fields. Sharma et al. [5] used Monte Carlo simulation technique for evaluating the reliability of complex systems.

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They analyzed that deep learning in the medical field and try to improve simulation but it can never replace Monte Carlo simulation.

Fuzzy set is a powerful mathematical tool for dealing with the complexity arising from uncertainty, similar to Monte Carlo simulations. The notion of fuzzy logic introduced by Zadeh[6]. Fuzzy sets have been used by many researchers to deal with uncertainty in many fields such as sociology, political science, medicine, etc., Smarandache et al. [7] developed the Neutrosophic set in 1998.Neutrosophic set is an essential mathematical tool for dealing with incomplete, indeterminate, and inconsistent informations. Neutrosophic set have membership, non-membership and indeterminacy functions. After the concept of Neutrosophic set, Wang et al. ([8], [9]) developed the interval valued neutrosophic fuzzy sets (INFS) and Single valued neutrosophic fuzzy set (SNFS).A SNFS has each membership degrees contained in [0,1] while an INFS has each membership degrees as an interval.

Fuzzy Sets, IFSs and NFSspossess various applications in medical field in parallel as Monte Carlo Simulation technique. Khan et al. [10] developed a X-bar control chart for dependent state sampling based on neutrosophic approach. Dhiman and Sharma [11] also developed a fuzzy inference system for the covid-19 pandemic. It uses a large and complex medical domain which helps doctors in choosing appropriate actions.Abdel et al. [12] studied the new medical image enhancement for COVID-19 in X-rays with type-2 NFSs and it is found that the entropy values are reduced to reduce the ambiguity within the chest X-ray image.There are many other applications of NFSs have been studied including single valued NFSs [13], in decision making ([14], [15]), in correlation coefficient [16], Efficiency analysis [17] etc. The notion of single valued neutrosophic fuzzy sets is also given in the existing literatures [18]. In this study the concept of single valued neutrosophic sets is applied to the graphs. Neurosophic fuzzy graph is also generalized over Pythagorean fuzzy sets [19], In this work some basic properties regarding the fuzzy graph are also extended. Apart for these, the concept of bipolar single neutrosophic graphs as the generalization of bipolar fuzzy graphs, N-graphs, intuitionistic fuzzy graph, single valued neutrosophic graphs and bipolar intuitionistic fuzzy graphs [20] were also given in the existing work.

The basic objective of this work is to develop a NMCSTand then to prove the applicability of given algorithm over medical diagnostic process. The entire work is focused on the dental problem of a patient. During the study, we will apply the neutrosophic approach to reduce the waiting time of the patient and the ideal time of the doctor.
The work done in this manuscript is divided into six sections, second section describes the basic concepts related to the work. Third section represents the proposed NMCST. The architecture of the proposed work is given in fourth section (shown in fig. 1). Fifth section describes the numerical computations. Thediscussions and interpretations of results have been discussed in the last section of the manuscript.

2. Basic Concepts

2.1. Neutrosophic fuzzy sets (NFSs)

Let χ be a universal set, then a NFSsN is characterized by a truth value μ_{N} , an indeterminacy value ι_{N} and a false value ν_{N} defined by

$$\mathrm{N} = \{(\omega, \mu_{\mathrm{N}}(\omega), \iota_{\mathrm{N}}(\omega), \nu_{\mathrm{N}}(\omega) : \omega \in \chi \ and\ \mu_{\mathrm{N}}, \iota_{\mathrm{N}}, \nu_{\mathrm{N}} \in]0^-, 1^+[\ )\}$$

with $0 \le \mu_{\mathrm{N}} + \iota_{\mathrm{N}} + \nu_{\mathrm{N}} \le 3$.

2.2.Operations on Neutrosophic Fuzzy Sets

Let$\mathrm{N}_1 = \{\mu_{\mathrm{N}_1}, \iota_{\mathrm{N}_1}, \nu_{\mathrm{N}_1}\}$ and $\mathrm{N}_2 = \{\mu_{\mathrm{N}_2}, \iota_{\mathrm{N}_2}, \nu_{\mathrm{N}_2}\}$ are two neutrosophic fuzzy sets then operations on these two neutrosophic sets are stated as;

2.2.1. $\mathrm{N}_1 \oplus \mathrm{N}_2 = \{\mu_{\mathrm{N}_1} + \mu_{\mathrm{N}_2} - \mu_{\mathrm{N}_1}\mu_{\mathrm{N}_2},\ \iota_{\mathrm{N}_1}\iota_{\mathrm{N}_2},\ \nu_{\mathrm{N}_1}\nu_{\mathrm{N}_2}\}$, $\oplus$ denotes addition.

2.2.2. $\mathrm{N}_1 \otimes \mathrm{N}_2 = \{\mu_{\mathrm{N}_1}\mu_{\mathrm{N}_2},\ \iota_{\mathrm{N}_1} + \iota_{\mathrm{N}_2} - \iota_{\mathrm{N}_1}\iota_{\mathrm{N}_2},\ \nu_{\mathrm{N}_1} + \nu_{\mathrm{N}_2} - \nu_{\mathrm{N}_1}\nu_{\mathrm{N}_2}\}$, $\otimes$ denotes multiplication

2.2.3. $\delta\mathrm{N}_1 = \{1 - \left(1 - \mu_{\mathrm{N}_1}\right)^{\delta}, {\iota_{\mathrm{N}_1}}^{\delta}, {\nu_{\mathrm{N}_1}}^{\delta}\}, \delta > 0$

2.2.4. ${\mathrm{N}_1}^{\delta} = \{{\mu_{\mathrm{N}_1}}^{\delta}, 1 - (1 - \iota_{\mathrm{N}_1})^{\delta}, (1 - (1 - \nu_{\mathrm{N}_1})^{\delta}\}$

2.3.Functions for NFSs

Let $\mathrm{N} = \{\mu_{\mathrm{N}}, \iota_{\mathrm{N}}, \nu_{\mathrm{N}}\}$ be a neutrosophic fuzzy set then score $\mathcal{S}(\mathrm{N})$, accuracy $\mathcal{A}(\mathrm{N})$ and certainty function $\mathcal{C}(\mathrm{N})$ are given by

2.3.1. Score function: $\mathcal{S}(\mathrm{N}) = \frac{2+\mu_{\mathrm{N}}-\iota_{\mathrm{N}},-\nu_{\mathrm{N}}}{3}$

2.3.2. Accuracy function: $\mathcal{A}(\mathrm{N}) = \mu_{\mathrm{N}} - \nu_{\mathrm{N}}$

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2.3.3. Certainty function: $\mathcal{C}(\mathrm{N}) = \mu_{\mathrm{N}}$

2.4. Ranking of NFSs

Let$\mathrm{N}_1 = \{\mu_{\mathrm{N}_1}, \iota_{\mathrm{N}_1}, \nu_{\mathrm{N}_1}\}$ and $\mathrm{N}_2 = \{ \mu_{\mathrm{N}_2}, \iota_{\mathrm{N}_2}, \nu_{\mathrm{N}_2}\}$ are two NFSs then ranking of these sets is defined as;

2.4.1. if $\mathcal{S}(\mathrm{N}_1) > \mathcal{S}(\mathrm{N}_2) \Rightarrow \mathrm{N}_1$ is greater than N_2.

2.4.2. if $\mathcal{S}(\mathrm{N}_1) = \mathcal{S}(\mathrm{N}_2)\ and\ \mathcal{A}(\mathrm{N}_1) > A(\mathrm{N}_2) \Rightarrow \mathrm{N}_1$ is greater than N_2.

2.4.3. if $\mathcal{S}(\mathrm{N}_1) = \mathcal{S}(\mathrm{N}_2), \mathcal{A}(\mathrm{N}_1) = \mathcal{A}(\mathrm{N}_2) and\ \mathcal{C}(\mathrm{N}_1) > \mathcal{C}(\mathrm{N}_2) \Rightarrow \mathrm{N}_1$ is greater than N_2.

2.4.4. if $\mathcal{S}(\mathrm{N}_1) = \mathcal{S}(\mathrm{N}_2), \mathcal{A}(\mathrm{N}_1) = \mathcal{A}(\mathrm{N}_2) and\ \mathcal{C}(\mathrm{N}_1) = \mathcal{C}(\mathrm{N}_2) \Rightarrow \mathrm{N}_1$ is equal to N_2.

3. ProposedAlgorithm for Neutrosophic Monte Carlo Simulation Technique (NMCST)

Proposed methodology of the proposed NMCSTis divided into following steps;

Step 1: Let $I_1, I_2 \ldots\ldots I_n$be n input factors. First, we convert each input factor into NFSs named as;

$$\mathrm{N}_1 = \{\mu_{\mathrm{N}_1}, \iota_{\mathrm{N}_1}, \nu_{\mathrm{N}_1}\}$$
$$\mathrm{N}_2 = \{\mu_{\mathrm{N}_2}, \iota_{\mathrm{N}_2}, \nu_{\mathrm{N}_2}\}$$
$$\vdots$$
$$\mathrm{N}_n = \{\mu_{\mathrm{N}_n}, \iota_{\mathrm{N}_n}, \nu_{\mathrm{N}_n}\}$$

Step 2: In this step, we estimated a score value to the each neutrosophic fuzzy sets $\mathrm{N}_i: i = 1,2, \ldots.n$ by using the score function

$$\mathcal{S}(\mathrm{N}_i) = \frac{2+\mu_{\mathrm{N}_i} - \iota_{\mathrm{N}_i}, -\nu_{\mathrm{N}_i}}{3} \text{for each i} = 1,2, \ldots \text{n}.$$

Step 3: In this step, we will calculate the probability of each input category with the formula given below;

$$\text{Probability} = \frac{\text{Total number of patient corresponds to perticular input factor}}{100}$$

and then find the cumulative probability for each factor.

Step 4: In this step, we will calculate the random intervalby using the scale parameter

$$\text{Random interval} = [a - b]$$

where a is the initial probability value and b is based on previous probability value.

Step 5: In this step, we estimate the waiting time by using the following formula;

Waiting time = Service start Score - Service End Score

4. Architecture of the proposed Neutrosophic Monte Carlo Simulation Technique

The architecture of the proposed model consists six major components as given below;

First component: In the first component, we construct a mathematical problem (dental problem) that consists or decision parameters; constants and calibration parameters; input parameters.

Second component: In the second component, we convert the input parameters (involve in the problem) into neutrosophic fuzzy sets (depends upon the nature of the data/ involve parameters).

Third component: To tackle the neutrosophic fuzzy set is quite complex process. To overcome with that situation, we convert the neutrosophic fuzzy set into a crisp value by using score function.

Fourth component: In the next component, we determine the probability of each involved parameters.

Fifth component: The fifth component, we determine a random interval in order to choose a random number based on the probability values of the variable.

Sixth component: In the last and sixth component, we estimate the service start score and service end score, based on these two scores we final find out the waiting time of the patient and idle time of the doctor.

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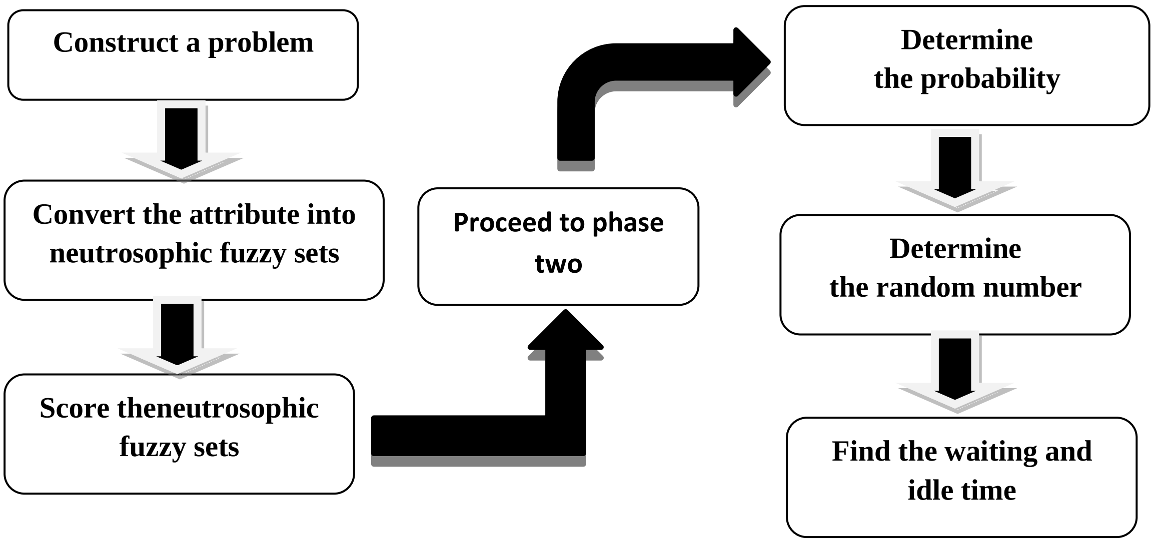

Figure 1: Neutrosophic Fuzzy Set-based Monte Carlo Simulation Technique

5. Numerical Computation

Let us consider a dental problem with the following types; filling, gum cleaning, oral checkup, crown and extracting.The task is to find the ideal and waiting time ofdoctor. Table 1 is describing the probability factor. Table 2 represents the cumulative probability and random number interval. The random number is described in table 3and table 4 representing the average waiting time and idle time.

Table 1: Probabilities

Categories	Time requires	Score function	Total patient	Score function	Probability
Filling	**50**(0, 0.2, 0.9)	**0.30**	**16**(0.9, 0.2, 0.1)	0.87	0.16
Gum cleaning	**45**(0.3, 0.5, 0.55)	**0.417**	**15** (0.8, 0.5, 0.3)	0.67	0.15
Oral checkup	**15**(0, 0.3, 0.9)	**0.27**	**20**(0, 0.5, 0.9)	0.20	0.20
Crown	**50**(0, 0.2, 0.9)	**0.30**	**10**(0, 0.3, 0.9)	0.27	0.10
Extracting	**40(0.2, 0.5, 0.8)**	**0.10**	**12(0.7, 0, 0.2)**	**0.84**	**0.12**

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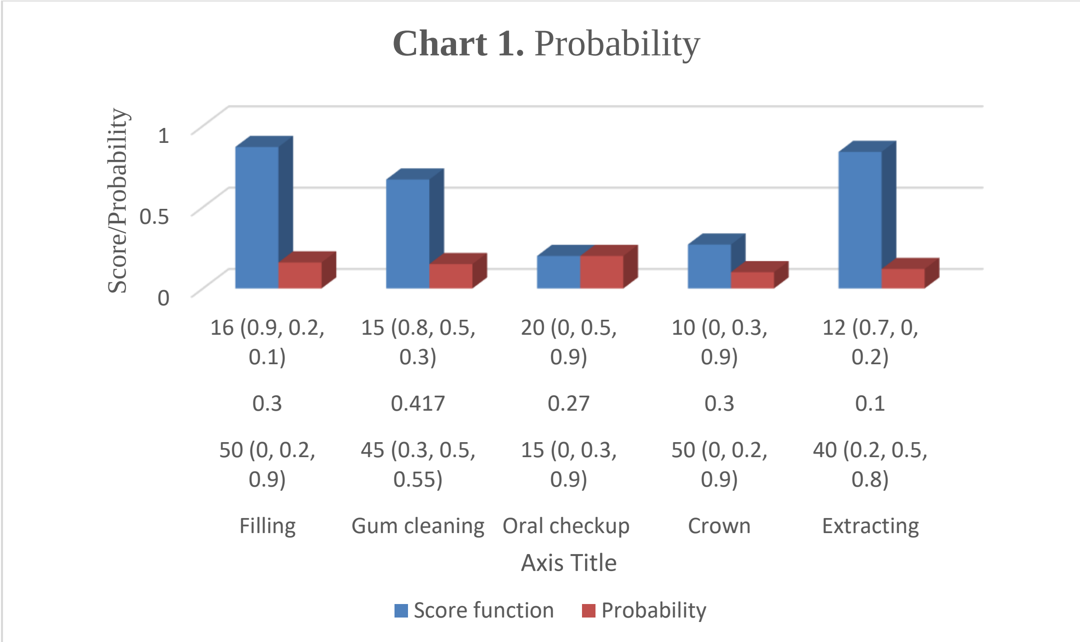

Table 1. and chart 1. Given the score function and probability values of each factor (filling, gum cleaning, extracting, crown and oral checkup). 50 is the time in minutes that a patient requires for the filling category, 45 is the gum cleaning require time, for oral checkup the require time is 15, for crown category time needed is 50 minutes, and 40 minutes is the time for extracting categories.

Table 2: Cumulative probability and random number interval

Categories	Probability	Cumulative probability	Random interval
Filling	0.16	0.16	00 – 15
Gum cleaning	0.15	0.31	16 – 30
Oral checkup	0.20	0.51	31 – 50
Crown	0.10	0.61	51 – 60
Extracting	**0.12**	**0.73**	**61 - 72**

Table 2. is given to calculate the cumulative probability and random interval for each category. In the of oral checkup category, the probability value is maximum, on the other hand the probability is minimum in case of crown category.

Table 3: Random Number

Patient	Arrival	Score	Random no.	Category	Time Needed

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1	10:00 AM **(0, 0.2, 0.9)**	0.30	12	Filling	0.30
2	10:30 AM **(0.1, 0.3, 0.8)**	0.34	15	Gum cleaning	0.417
3	11:00 AM **(0.2, 0.5, 0.7)**	0.34	02	Oral checkup	0.27
4	11:30 AM **(0.3, 0.3, 0.8)**	0.74	15	Gum cleaning	0.417
5	12:00 PM **(0.4, 0.5, 0.6)**	0.77	08	Oral checkup	0.27
6	12:30 PM **(0.5, 0.3, 0.5)**	0.57	25	Filling	0.30
7	01:00 PM **(0.6, 0.7, 0.3)**	0.54	45	Crown	0.30
8	01:30 PM **(0.7, 0.2, 0.2)**	0.77	35	Extracting	0.10
9	02:00 PM **(0.9, 0.1, 0.2)**	0.87	22	Oral checkup	0.27
10	**02:30 PM (0.9, 0.2, 0.3)**	**0.80**	**17**	**Oral checkup**	**0.27**

Table 3. illustrated the time needed for each of the categories according to the random selection of a patient. In this table, we first choose a random number 12 for which the time require value is 0.30 unit, and for random number 17 the require time is 0.27 unit.

Table 4: Average waiting time and idle time

Patient	Arrival Score	Services Start	Score	Time needed	Service End Score	Waiting Time	Idle Time
1	0.30	10:00 AM **(0, 0.2, 0.9)**	0.30	0.30	0.60	0.0	0
2	0.34	10:50 AM **(0.1, 0.2, 1)**	0.60	0.417	1.017	0.26	0
3	0.34	11:35 AM **(0.2, 0.2, 1)**	0.64	0.27	0.91	0.677	0
4	0.74	12:00 AM **(0.5, 0, 0.1)**	0.80	0.417	1.087	0.17	0
5	0.77	12:45 PM **(0.6, 0.1, 0)**	0.83	0.27	0.87	0.317	0

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6	0.57	01:00 PM **(0.6, 0.5, 0.3)**	0.60	0.30	0.90	0.3	0
7	0.54	01:50 PM **(0.8, 0.5, 0)**	0.77	0.30	1.07	0.36	0
8	0.77	02:40 PM **(0.9, 0.2, 0)**	0.90	0.10	1.0	0.3	0
9	0.87	03:40 PM **(0.9, 0, 0.1)**	0.94	0.27	1.14	0.13	0
10	0.80	03:55 PM **(1, 0.5, 0)**	0.84	0.27	1.11	0.34	0
				waiting time	**2.85**	**0**	

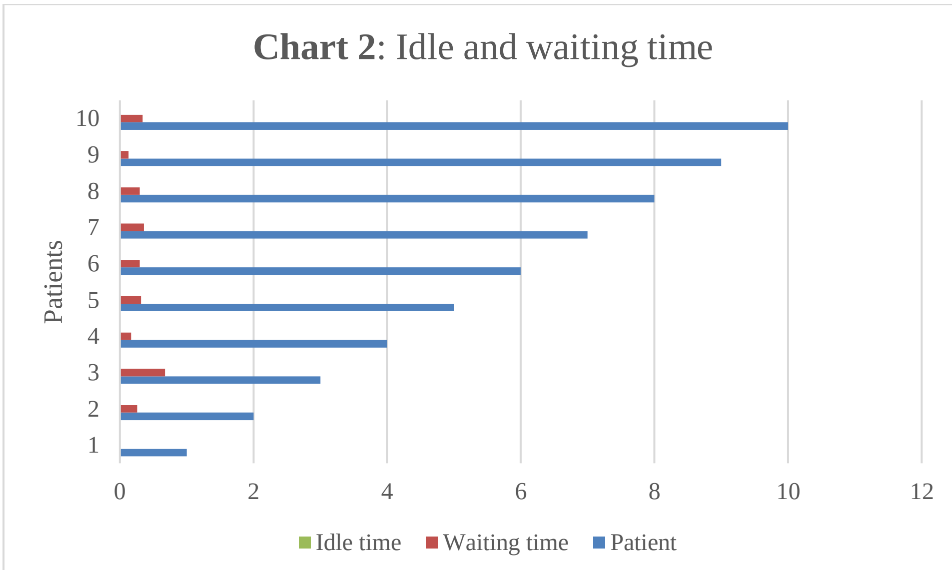

Table 4. and chart 2. Shown the waiting time of the patient and idle time of the doctor. Throughout the study the idle time of the doctor is zero. The maximum waiting time of the patient is 0.677 unit and the minimum waiting time of the patient is 0 unit.

6. Conclusion

From the numerical computation, we have the following observations;

i. It can be observed from table 1, the time required for filling and crown is high i.e., about 50 minutes. While the time require for gum cleaning is less high i.e., about 45 minutes. The time needed for extracting is moderate i.e., 40 minutes and the time needed for oral checkup is less i.e., about 15 minutes. The score value for filling is 0.87 (higher) and score function value for oral checkup is 0.20 (lesser).

ii. From the table 2, the cumulative probability for the extracting is 0.73. The cumulative probability for the crown category is 0.61. The cumulative probability for the oral checkup 0.51. The cumulative probability for the crown category is 0.31 and for filling is 0.16.

iii. The table 3 indicates that the arrival scored values of the patients, for patient nine is 0.87 i.e., higher and the arrival scored value for the patient one is low i.e., 0.30.

iv. In the table 4, we can observe that the total waiting time of the patients is 1.76 hours and the idle time of the doctor is 0.

We also conducted a comparative study (shown in table 5)of our proposed NMCST with the existing model based on fuzzy logic approaches and intuitionistic logic approach.

Table 5: Comparative study with the previous approaches

	Fuzzy Approach	**Intuitionistic fuzzy approach**	**Neutrosophic approach**

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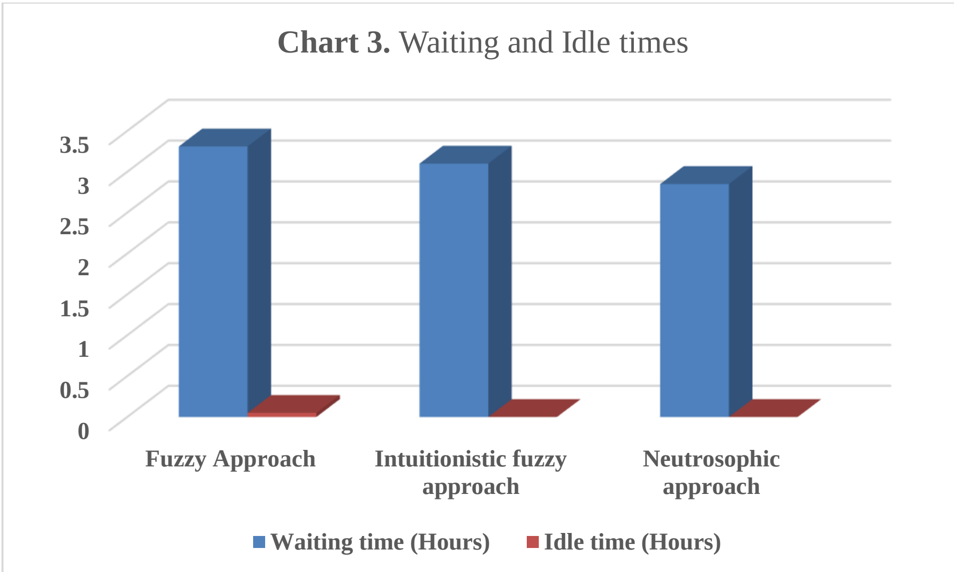
Waiting time (Hours)	3.31	3.10	2.85
Idle time (Hours)	0.0	0.00	0.00



It can be easily observed from the chart 3. thatin case of fuzzy approach the waiting time of the patient is 3.3, on the other hand, in case of intuitionistic fuzzy approach the waiting time of the patient is 3.10 (lesser than fuzzy approach). While in case of neutrosophic approach the waiting time of the patent 2.85, which is much lesser as compare to fuzzy and intuitionistic fuzzy approaches. Although, the idle time of the doctor remains same in all three cases.

Compliance with Ethical Standards

Conflicts of interest: Authors have no conflict interest.

Research involving human participants and/or animals: This research neither involves human nor animals.

Contribution statement

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