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Novel Framework for Selecting Cloud Provider Using Neutrosophic and Modified GAN

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Abstract: Cloud computing is very important for many companies in the process of progress. The main problem for any company when transferring their work to the cloud is selecting the most suitable cloud provider among the availability of different cloud service providers with different properties and different alternatives. This paper introduces a novel framework that can be used for selecting the most suitable provider in the case of missing values in the evaluation of alternatives. The framework is composed of two steps; the first step in the framework is about using the Modified Generative Adversarial Network (M-GAN) for data imputation of missing data. The modified version of GAN has achieved an accuracy of nearly 0.94. The second step is the Multi-Criteria Decision-Making (MCDM) neutrosophic algorithm for selecting the most suitable provider according to different eight criteria (Availability, Throughput, Successibility, Reliability, Latency, Response time, Response Time of Customer Services, and Cost). According to the experiments done in the paper, the Novel framework has achieved success in choosing suitable providers. the presented model achieved 0.05 (sec) computation time for 1000 providers rather than 0.057 (sec), 0.061 (sec), and 0.065 (sec) in other mentioned works.

Keywords: Cloud service Provider, Neutrosophic, GAN, Deep Learning.

1 Introduction

Cloud computing is one of the most important technologies available to a wide range of organizations. Cloud computing helps organizations use the most needed services online without the need to install them physically. The main problem for any organization is how to choose a suitable provider according to the available solutions and organizational requirements [1, 2, 3]. However, selecting a suitable provider process of available cloud services remains a difficult task for any organization and stockholder, particularly in the case of missing data for a variety of reasons.

1. **Numerous criteria:** There are a large number of criteria and different requirements for organizations. For example, the requirements for each organization are so different that many organizations need to reduce costs while other organizations need to increase availability and security with a large budget.
2. **Missing values of evaluations:** The shortage and the missing values for each criteria (Availability, Throughput, Successibility, Reliability, Latency, Response time, Response Time of Customer Services, and Cost) can affect the final decision of selecting a suitable provider, so the imputation of the missing value can be one of the most important tasks for the stack holder before the decision-making process.
3. **Experts' opinions:** Experts' opinions can affect positively or negatively the final process of choosing the provider among the available providers.

The main purpose of the framework is to choose the best provider among the available providers according to the organization's requirements, especially in the case of missing data for the evaluation of each criteria. The framework divides the work into two stages; the first stage is how to deal with missing evaluation criteria using the modified version of GAN [4, 5, 6], and the second stage is about using multi-criteria decision-making based on a neutrosophic algorithm for choosing the best

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available provider according to organization needs and requirements.

Missing data is a hard and complex problem for each stockholder in the process of choosing suitable providers. Data may be missing or lost for different reasons, such as that it was never collected or records were missed. The GAN deep learning architecture can be used to generate missing or lost values. The GAN is divided into two parts; the first part is called a generator for generating the missing data, and the second part is called a discriminator for differentiating between the generated data and the available data. The discriminator is trained to reduce the classification loss, and the generator is trained to maximize the discriminator's misclassification rate.

Smarandache first introduced Neutrosophy in 1995 [7]. Neutosophic sets include the classical set, fuzzy set, interval - valued intuitionistic set, etc. To make the use of neutrosophic sets easier, the single-valued neutrosophic set (SVNS) was developed [8]. Its membership is composed of three elements: truth, indeterminacy, and falsity. In a neutrosophic set, indeterminacy is quantified explicitly, and truth, indeterminacy, and falsity all have distinct membership functions. This concept is crucial in a variety of settings, such as an information coalition, when seeking to combine the data from various sensors.

Multiple domains have used the same valued neutrosophic set [9, 10, 11]. When a decision maker expresses an opinion about a statement, he or she can remark that it is 50% true, 60% false, and 20% uncertain.Neutosophic is thus one of the best models for actual decision-making processes since it takes into consideration truth (certain/yes), indeterminacy (unsure), and falsity (false/no) membership functions. As a result, it could handle vague, insufficient, and conflicting information successfully.

In turn, this will produce more accurate information, which will aid in making the appropriate choices. Although many of these applications are pricey, it can also be employed in a variety of professions and adoption scenarios [12, 13, 14, 15].

MCDM based on a neutrosophic algorithm is used to select the best suitable provider according to the organization's needs and requirements by analyzing the alternatives with respect to criteria weights that may be different from one organization to another according to their priorities [16, 17, 18, 19, 20, 21]. Some organizations pay attention to cost in the first place, another organization may prefer the response time, and another may go for the availability. All these organizations with different interests and priorities will find their needs in this framework that will help them choose the best suitable cloud provider according to their own needs.

Many algorithms have been published to handle the problem of selecting suitable providers in the cloud, such as Fuzzy [22, 23, 24], TOPSIS [25], AHP [26, 27, 28, 29], ELECTRE [30], and neutrosophic VIKOR [31, 32, 33, 34]. All of these methods can deal with the problem, but these algorithms cannot achieve high accuracy when missing data. The proposed framework can handle this problem.

The contributions of this paper can be summarized as follows:

- The novel framework can use modified GAN to manage different data types with missing values.
- The Framework uses MCDM algorithm based on neutrosophic for achieving success in selecting the best suitable provider while respecting the degree of intermediary.
- Neutrosophic Algorithm is modified to improve the computation time.
- The proposed framework can choose the suitable provider in the case of incompatible criteria, differences in interest in decision-makers and imprecision issues.

The rest of this paper is organized as follows. Section 2 introduces the related works as well as the main findings of the research. Section 3 introduces the methodology and describes the main stages in the proposed framework. Section 4 demonstrates the discussion and experimental results. Section 5 is the paper's conclusion.

2 Related Work

In this section, An overview of the various Multi-Criteria Decision Making (MCDM) strategies used to choose the best cloud provider.

Choosing and making decisions is a major difficulty for decision-makers in many businesses [1, 2].

The challenge for businesses is to select the best cloud service providers that can meet their needs due to the diversity of cloud service providers [3, 35].

Calculating the cloud's best demands using cloud estimating the performance of a company's services is a difficult process [1, 36, 37].

It is initially important to establish the standards for calculating and choosing the best cloud services. Numerous studies have identified the important parameters for gauging the performance of cloud services [16, 17, 18, 19, 20, 21, 38, 39, 40, 41, 42].

Numerous examples of the cloud services evaluation and selection process are investigated using a variety of techniques.

In [43], Garg *et al.* used the analytic hierarchy process (AHP) to gauge how well cloud services are working for a company.

In [8], B. Martens proposed a mathematical model for decision-making for selecting cloud computing in a multi-sourcing environment..

In [26], Safari *et al.* proved that AHP is a successful and efficient decision-making method, yet decision-makers' subjectivity can result in doing pairwise comparisons with uncertainty.

In [2], M. Sun. used the fuzzy set theory to get around this limitation. It can be used to solve a variety of issues because it involves some level of uncertainty, but the result is always some-what ambiguous, as shown in [28, 29].

In [44], Menzel *et al.* used the analytical network process (ANP) incorporating zero-one goal programming to determine the standard of cloud services.

In [22], Wibowo *et al.* employed a technique to make fuzzy multi-criteria decisions according to the TOPSIS cloud computing assessment framework.

In [23, 24], C.-T. Chen and CH Yeh used a new hybrid fuzzy technique that incorporates fuzzy sets and VIKOR.

There are many models for decision-making that combine neutrosophic sets for assessing and choosing convenient cloud service providers presented in [25, 30, 31, 32, 33, 34, 45, 46, 47, 48].

Neutrosophic set theory has grown in significance in many decision-making situations because it gives decision-makers the freedom to evaluate the options in language terms. It has been incorporated with several MCDM techniques and aids decision-makers in resolving any uncertainty in their judgment.

In [49], Liu *et al.* assigned that DEMATEL, a decision-making, experiment, and evaluation facility approach, was used to choose a transportation service provider as a solution. After converting the expert language ratings to neutrosophic values using a neutrosophic set, the transport service providers were rated using DEMATEL.

In [50], Abdel-Basset *et al.* combined DEMATEL and neutrosophic set theory to study the supply chain management supplier selection criteria. Expert judgment was adjusted using the neutrosophic set, and the most important factors affecting supply chain management were found using DEMATEL.

In [51], Karasan *et al.* employed a CODAS (combined distance-based assessment) and an integrated neutrosophic set, it was determined where the wind energy facility was. To deal with the uncertainties, they employed an intermediate values neutrosophic set, and CODAS was used to locate the best area for a wind generator.

In [52], Abdel-Basset *et al.* additionally expanded TOPSIS and ANP for the supplier selection problem using neutrosophic set theory. We may therefore conclude from the foregoing considerations that the neutrosophic set merged with a variety of MCDM techniques to address a variety of selection difficulties.

One of the main obstacles for cloud consumers in the realm of cloud computing is choosing a cloud service. Several authors have offered strategies for choosing cloud services.

In [53], Godse *et al.* established a selection technique to SaaS services using the AHP method. They assessed the SaaS service using a variety of QoS factors, such as usability, budget, function, architecture, and vendor credibility, and then used AHP to score it. To demonstrate the strategy's value, a case study of the Salesforce automated services was conducted.

In [54], Dastjerdi and Buyya have looked into how the selection problem might be mapped in a cloud environment and in other settings, such as online services, grids, etc. They also developed a taxonomy to cloud-based quality of service operations. MAUT and the outranking approach were generally grouped together as the MCDM techniques. They provided a sample using the MAUT category approach and AHP to pick a cloud provider.

In [55], Whaiduzzaman *et al.* proposed a taxonomy for choosing a cloud service based on MCDM techniques. They reviewed numerous MCDM techniques along with comparative analyses of their use in diverse fields.

In [56], Garg *et al.* created the SMICloud framework, which uses the AHP approach to rate cloud services. To calculate the various functional and non-functional SMI framework QoS characteristics, they developed equations. AHP is used to determine each QoS metric's priority when choosing which cloud services to use. The cloud services were ranked using the priority vector that was created by aggregating all QoS indicators.

In [57], Baranwal and Vidyarthi built a cloud service rating system employing a better rank voting process. They also discovered a few new QoS metrics to add to the SMI architecture, which aids cloud consumers in assessing cloud computing. Software and consumer QoS measurements made up the two main groups. Consumer QoS includes QoS relevant to the cloud user experience, which is important from the user's point of view. Software QoS is concerned with application performance. The best cloud service was chosen using the new rank method of voting. It views the QoS that they offer as the ballot and the cloud services as the candidates on a vote. Depending on the services they offer, each CSP receives a QoS rating. To determine the best cloud service, the scores of each CSP according to each QoS were pooled.

In [58], Sidhu and Singh declared that AHP and TOPSIS were used to construct a new trust evaluation framework that was tasked with finding a trustworthy cloud service. The appropriateness of each QoS option is assessed based on the subjective evaluations of each QoS made by cloud users using AHP. In order to determine the optimal cloud service based on AHP-established service reliability and weights, the TOPSIS was utilized.

In [59], Tripathi *et al.*an approach for assessing cloud services where QoS indicators are interdependent was offered. Their study uses an ANP model to mimic the relationship between QoS requirements and cloud service ranking. A node with edges for dependencies is used by ANP to represent cloud computing and QoS parameters as nodes. After integrating all priority vectors to score cloud computing, interdependence metrics are prioritized using the comparison matrix pairwise. As there are more cloud services and QoS requirements, ANP gets more challenging.

In [60], Kumar *et al.* established a flexible framework that allows consumers and cloud experts to communicate their ideas linguistically for choosing cloud services in a fuzzy environment. They selected a cloud service using fuzzy TOPSIS and AHP. AHP was used to calculate the importance of the QoS criteria, and a triangular fuzzy numbers and TOPSIS were coupled to manage fuzziness before scoring cloud computing.

In [61], Kumar *et al.* additionally developed A novel architecture that used TOPSIS and AHP to score cloud computing in an open environment was also developed. The AHP technique is used to determine the importance of each QoS parameter based on the subjective assessment of cloud users. Not to mention, TOPSIS was used to evaluate cloud computing based on QoS evaluations from cloud comparison service suppliers.

In [62], Lee and Seo developed a system for deciding which IaaS computing platform is best in a challenging circumstance. They used the scorecard to determine the most important Qos parameters from categories like business process, finance, etc. and the fuzzy Delphy technique to determine the most important Qos criteria from each element. The next step involved ranking the cloud services by determining the priority vector for each QoS metric using triangle fuzzy values and AHP.

In [63], Radulescu *et al.* developed a ranking system for cloud computing using entropy and the upgraded TOPSIS technique. The entropy approach was used to calculate the weights of the QoS parameter. In selecting the most appropriate cloud service, they changed the conventional TOPSIS by substituting the Minkowski length for the Equilidean length.

In [64], Basu and Ghosh constructed a reliable system of reversed ranks using fuzzy TOPSIS to rate cloud computing in a fuzzy context. However, it cannot handle measurements for interdependent QoS.

In [65], Jatoth *et al.* used AHP and Grey TOPSIS to develop a framework for service selection.In order to rank the cloud services, they combined TOPSIS and Grey set theory and used AHP to determine the relevance of QoS metrics.

The previous discussions demonstrate that selecting a cloud service provider is a decision-making problem, and most writers used MCDM techniques to determine the best cloud service providers. However, neutrosophic settings do not benefit from the frameworks for selecting cloud services that have been researched in the literature. Neutosophic set theory has lately gained importance as a way to more effectively handle the problem of uncertainty. So, in order to rank the cloud services, For the first time, neutrosophic set theory has been merged. The new approach rates cloud services in the neutrosophic environment efficiently and firmly. Numerous examples of the cloud services evaluation and selection process are investigated using a variety of techniques. Numerous examples of the Generative Adversial Networks (GAN) using a variety of techniques have been used in different applications. In [4], Swiderski By using the deep learning method, proposed a novel neural system for mammography recognition. The use of AGAN to supplement the input set of images provided to the CNN classification system was a significant innovation. The normal test images may be correctly reconstructed using AGAN, which was trained on the normal set of images. The reconstruction of the anomalous images, however, is not similar. The disparities between the set of normal images (creating a uniform set of images) and the abnormal image set, which is now represented by the originals and their dissimilar reconstructions, have increased as a result. Additionally, we have suggested certain changes to the GAN structure (called AGAN). In [5], Zhong-Sheng Chen described a brand-new virtual sample generation technique that makes use of virtual samples to boost soft model prediction accuracy. They created methodology consists of two steps. The CVT sampling-related component is utilized to create fresh samples and then uniformizes data distribution. An implicitly probabilistic model called RegCGAN, which is used to combine the results of fresh samples, is another component. By presenting two accuracy metrics (MSE and MAE) and one distribution goodness indicator. In [6], authors have demonstrated that the best attention unit for enhancing CNN performance is channel attention. K-means has a great ability to remove unusually-shaped generated images, magnifying the accuracy training from PGGAN augmentation. They infer that the data performance can be enhanced by using a min-max contrast between the discriminator and generator models of GAN.

Most of previous research focuses on MCDM with consistent and clear datasets. In our research, we intend to focus on two points of view, which are: handling missing data by using modified GAN [38-40] and achieving better results than previous research using the proposed Modified Neutrosophic Algorithm. This work, in our opinion, is the first to evaluate cloud services by use of a modified GAN and neutrosophic set theory.

3 Material and Methods

This section describes the process used to create the framework that will be used to choose the most suitable provider, which can be summarized in the following steps:

Steps of methodology: Step 1: Data Acquisition: Identify the Alternatives and Available Providers.

Step 2: Fill in the blanks with a modified GAN.

Step 3: Choose the best suitable provider among the available providers using a multi-criteria decision-making algorithm based on neutrosophic.

And Figure 1. summarizes the entire processes that were used to create this framework.

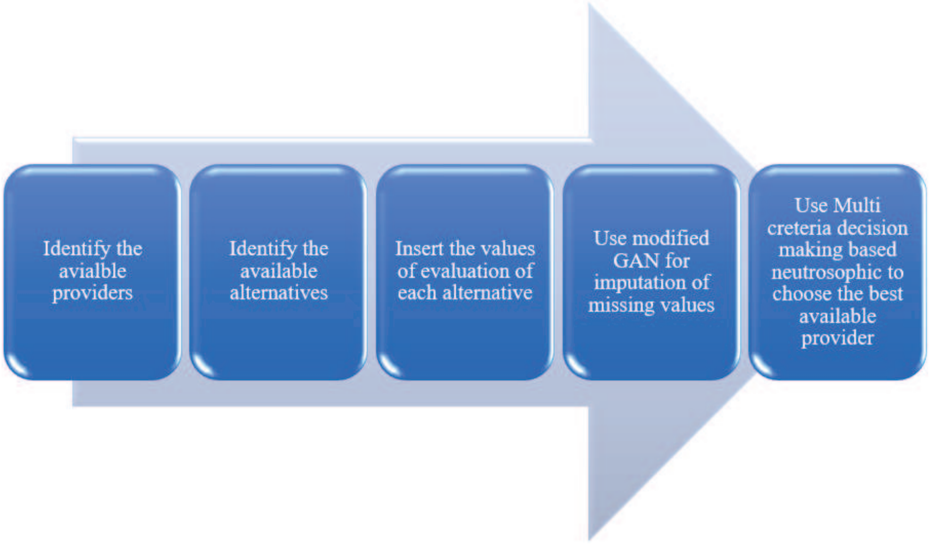

Fig. 1: Methodology steps

3.1 Cloud Sevice Provider Dataset

The framework depends on the dataset collected to describe different providers. The dataset collected the Quality of Service (QoS) performance of 80 cloud computing services (called a computing dataset) from the Network-Testing Website of Cloud Harmony [66]. The dataset also uses different parameters for assessing different servers, such as availability, successibility, throughput, etc. The dataset contains nearly 1500 rows. The main problem with the dataset is the missing values, which need imputation. The paper uses a modified version of GAN for imputation of the missing values to be used in a selected case study in the next section.

3.2 Imputation Missing Values Stage

GAN is a deep learning model which contains two parts; the first part, which is called the generator, which is used to generate the missing data in the imputation process, and the other part, which is called the discriminator. This part is used to differentiate between the real or original data and the generated data by the generator part. The framework uses a modified version of GAN, which is called M-GAN, and consists of four steps.

Given The cloud dataset X, M matrix, which describes the missing values in the dataset, Z is the mean value in the dataset, which has values in the dataset.

1. Build the generator part using the next equation, which is called G, to produce the output using Equations 1 and 2.

$$\bar{X} = G((X \circledcirc M + Z \circledcirc (1 - M)), M) \qquad (1)$$

$$\bar{X} = G((X \circledcirc M + \bar{X} \circledcirc (1 - M)), M) \qquad (2)$$

2. Build Discriminator D Using the following equations, the B value is a randomly generated value, output is the output value which is fake or real, and value which provides more information to the discriminator as mentioned in Equations 3, 4 and 5.

$$h \in H = B \circledcirc M + 0.5(1 - B) \qquad (3)$$

$$B = (B_1, \ldots, B_d) \in \{0, 1\}^2 \qquad (4)$$

$$D_{output} = D(\bar{X}, H) \qquad (5)$$

Where, M , G ,X, Z and B are Circled Ring Operator, Matrix, Generator function, cloud dataset, mean value and parameters of the discriminator respectively.

3. Start the training process using mini patches and sample K using Equations 6, 7, and 8, and refer to the combination of the loss of continuous and categorical variables with separate weights.

$$D_{loss} = \max_{D} \left[M \log D(\bar{X}, H) + (1 - M) \log(1 - D(\bar{X}, H)) \right] \qquad (6)$$

$$G_{loss} = \min_{G} (L_G + \alpha L_{M1} + \beta L_{M2}) \qquad (7)$$

$$L_G = -(1 - M) \log D(\bar{X}, H) \qquad (8)$$

4. Return to the original scale.

3.2.1 Performance Metrics

The framework uses five different performance matrices to evaluate the performance of the modified GAN in data imputation. The Framework uses recall, F1-score, precision, accuracy, and specificity, which have been calculated by the next mentioned equations.

$$Precision = \frac{TP}{TP+FP} \tag{9}$$

$$Recall = \frac{TP}{TP+FN} \tag{10}$$

$$F1 = \frac{2 \times Precision \times Recall}{Precision + Recall} \tag{11}$$

$$Accuracy = \frac{TP+TN}{TP+FN+TN+FP} \tag{12}$$

$$Specificity = \frac{TN}{TP+FP} \tag{13}$$

3.3 Multi-criteria Selection Method Based on Neutrosophic

This part of the paper describes the MCDM method and how method handles the problem of selecting the most suitable provider after imputation of the missing data using the modified GAN. The proposed method based on the neutrosophic divides the data into three sets: a true set to describe the degree of the true; a false set to describe the degree of the false; and an intermediate set to describe the degree of intermediacy. Figure 2 displays the block diagram of the selection process of the provider using the neutrosophic-based method. As mentioned in the block diagram, the process of selection consists of six steps:

1. Identifying the criteria of the cloud service provider and the features that must be found in this cloud service provider.
2. Identifying alternatives and parameters that will be the basis of the evaluation process for cloud service provider options.
3. Building a hierarchy using the alternatives and criteria to create the structure of the framework.
4. Converting the data to a neutrosophic set that will contain three parameters (truth, indeterminacy, and fault).
5. Calculating the weights for each alternative according to the previous identification criteria.
6. Ranking the alternatives to choose the best cloud service provider among all options.

3.3.1 Preliminaries related to a neutrosophic set

Definition 1.

In Neutrosophic set, the level of indeterminacy (I) was first introduced as a stand-alone element by the neutrosophic set (NS) [67].

The following describes the truth value for the neutrosophic set:

Consider the set N, which is defined as follows: $\mathbf{N} = \{(\mathbf{T},\mathbf{I},\mathbf{F}) : \mathbf{T},\mathbf{I},\mathbf{F} \subseteq [0,1]\}$, a neutrosophic valuation. n is a mapping from the set of propositional formulae to N, meaning that for each sentence x, we have the formula $N(x) = (T,I,F)$.

$$N = \{x, T_N(x), I_N(x), F_N(x) | x \in X\} \tag{14}$$

where

$T_N(x) : X \rightarrow]0,1[$
$I_N(x) : X \rightarrow]0,1[$
$F_N(x) : X \rightarrow]0,1[$

Definition 2.

Single valued neutrosophic set (SVNS) was developed to make neutrosophic sets and set-theoretic operators more useful in practical applications. A single-valued neutrosophic set was introduced as a particular example of a neutrosophic set, which is a specialization of intuitionistic fuzzy sets to handle incomplete information. [67].

A single value neutrosophic set N is defined by:

$$N = \{x, T_N(x), I_N(x), F_N(x) | x \in X\} \tag{15}$$

where

$T_N(x) : X \rightarrow [0,1]$
$I_N(x) : X \rightarrow [0,1]$
$F_N(x) : X \rightarrow [0,1]$

Definition 3.

Single-valued neutrosophic numbers (SVN numbers) are represented by the symbol $N = (x,y,z)$, where $x,y,z \in [0,1]$ and$a+b+c \leq 3$. Sometimes, while solving problems in the real world, we can represent some qualitative information by using linguistic phrases like "good" or "bad" rather than numbers. Many traditional multi-criteria decision-making methods have been modified for neutrosophic problems [68].

Let $N = \{x, T_N(x), I_N(x), F_N(x) | x \in X\}$ and $M = \{x, T_M(x), I_M(x), F_M(x) | x \in X\}$ be two single value neutrosophic set, the following calculations are denoted by:

$$N \oplus M = T_N(x) + T_M(x), T_N(x)T_M(x), I_N(x)I_M(x), F_N(x)F_M(x) \tag{16}$$

$$N \otimes M = T_N(x)T_M(x), I_N(x) + I_M(x) - I_N(x)I_M(x), F_N(x) + F_M(x) - F_N(x)F_M(x) \tag{17}$$

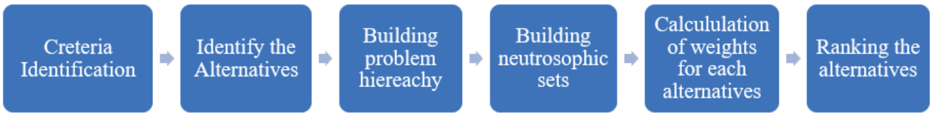

Fig. 2: Block diagram of the multi-criteria selection method based on neutrosophic

3.3.2 Building Neutrosophic Sets

Step 1: Determine the linguistic terms as well as their neutrosophic set.

The language terms that will be used to evaluate the alternatives should be identified by experts, who should then specify the neutrosophic set value for each linguistic term. In all subsequent evaluation processes, these linguistic phrases will be used.

Step 2: Create a Decision Matrix (DM) with a single value neutrosophic set

Allow experts to analyze each alternative's linguistic opinion in order to evaluate each criteria by comparing criteria and alternatives using the linguistic phrases they identified earlier. After computing the choice matrix, the linguistic word will be converted to a neutrosophic set value using the mapping function.

Step 3: Determine the weights for each criteria

The experts will offer linguistic opinions for each need based on linguistic expressions they have previously identified. Using a proper mapping function, the linguistic expressions offered from the specialist for each criteria are transformed into NS.

Step 4: Make the Weighted Decision Matrix calculations (WDM)

Multiply DM with the weights results in the computation of the WDM in the neutrosophic set.

$$D^{w} = D \otimes W \tag{18}$$

Step 5: Calculate the single valued neutrosophic negative (SVNNIS) and positive ideal solution (SVNPIS)

The two forms of criteria that can be utilized to select the best alternative are benefit and cost criteria. Cost criteria should have the least value possible, whereas benefit criteria should have the highest value possible according to experts. The SVNPIS and SVNNIS were developed with cost and benefit considerations in mind. SVNPIS and SVNNIS, respectively, are the best and worst options. SVNPIS and SVNNIS are calculated using Equations 19 and 20, respectively.

$$V^{+} = SVNPIS = [(T_1^{+}, I_1^{+}, F_1^{+}), (T_2^{+}, I_2^{+}, F_2^{+}), \ldots, (T_3^{+}, I_3^{+}, F_3^{+})] \tag{19}$$

$$V^{-} = SVNPIS = [(T_1^{-}, I_1^{-}, F_1^{-}), (T_2^{-}, I_2^{-}, F_2^{-}), \ldots, (T_3^{-}, I_3^{-}, F_3^{-})] \tag{20}$$

where

$$(T_1^{+}, I_1^{+}, F_1^{+}) = \begin{cases} < 1.0, 0.0, 0.0 > for j \in J_1 \\ < 0.0, 1.0, 1.0 > for j \in J_2 \end{cases}$$

$$(T_1^{-}, I_1^{-}, F_1^{-}) = \begin{cases} < 0.0, 1.0, 1.0 > for j \in J_1 \\ < 1.0, 0.0, 0.0 > for j \in J_2 \end{cases}$$

Step 6: Apply the SVNPIS and SVNNIS to calculate the score for each option

Calculate the score for each option using SVNPIS (V+) and SVNNIS (V-). The score measurement that was employed to determine the score between alternative Vi from V+ and V- is depicted in Equations 21 and 22, respectively.

$$S_i^{+} = D^{W}.V^{+} = \sum_{j=1}^{n} T_{D^W}.T_{V^+} + I_{D^W}.I_{V^+} + F_{D^W}.F_{V^+} \tag{21}$$

$$S_i^{-} = D^{W}.V^{-} = \sum_{j=1}^{n} T_{D^W}.T_{V^-} + I_{D^W}.I_{V^-} + F_{D^W}.F_{V^-} \tag{22}$$

Step 7:Calculate the consistency of each option

The consistency of each option is calculated using Equation 23. The Consistency demonstrates how the option is to SVNNIS (V-) and SVNPIS (V+).

$$C_i = \frac{S_i^{-}}{s_i^{-} + S_i^{+}} \tag{23}$$

where the proximity score of option i is represented by C_i. According to each option's proximity index, the choices are sorted.

Step 8: Rank the options

The proximity index is used to rank the options, with the option with the highest closeness index value being ranked best and the option with the lowest closeness index value being ranked worst.

Algorithm 1 Pseudo-code of Neutrosophic Algorithm

```
Input: n: number of Cloud Service Providers, m: number of Criteria Parameters
Output: Classification of Cloud Service Providers
Input Linguistics terms and their neutrosophic set by experts
Fill up the Linguistic Term with DM and the weights for each criterion.
Use Equation 18 to transform the DM and Weight of each QoS into a Neutrosophic DM and Weight Vector.
for $< T(x_{i.j}), I_A(x_{i.j}), F_V(x_{i.j}) >$ in DM do
    Use Equation 17.
end for
Compute SVNPIS and SVNNIS with respect to the DMs using Equations 19 and 20.
Calculate the Score of each alternative from SVNPIS and SVNNIS
for $i = 1$ do
    $S_i^+ = D^W.V^+$
    $S_i^- = D^W.V^-$
end for
Calculate the Consistency of each alternative using Equation 23.
for $i = 1$ do
    $C_i = \frac{S_i^-}{S_i^- + S_i^+}$
end for
Sort the cloud service providers by $Ci$ in descending order.
```

3.3.3 Building Neutrosophic Algorithm

First, depending on each cloud service provider's characteristics, specialists have specific linguistic requirements. To reduce subjective randomness, logical decision-making is used in connection with the neutrosophic set. A modified GAN technique is utilized to find the values because it's possible that some of them are missing. Then, by identifying uncertainty and applying the incomplete information provided by the selection committee, the weights of each linguistic value (DM) and attribute are continually determined. The DM's preferences are compiled using the connections between the attributes. The weights of the DMs are determined rationally and applied for aggregation in this paradigm, in contrast to previous methods. The Neutrosophic Method is then expanded, and the decision matrix and weights of the attributes are used to define the priorities of the cloud service providers. The framework is put through two assessments; one that compares it to current ways and the other that performs an awareness evaluation of various approaches to assist in explaining its positive and negative aspects. The proposed Neutrosophic Algorithm's pseudo-code is shown in Algorithm 1. The flowchart of the neutrosophic algorithm is shown in Figure 3.

4 Results and Discussion

4.1 Case Study

The case study in this paper uses five providers: MAPPMatching, Compound2, USDAData, GBNIRHolidayDates, and CasUsers and eight different criteria.

4.1.1 Criteria Selection

The first step in the case study of selecting the best suitable provider is identifying the criteria which have been used to asses each provider as mentioned in Figure 4. which can be defined as :

Response Time: Time taken to send a request and receive a response.

Availability:Number of successful invocations/total invocations.

Throughput: Total Number of invocations for a given period of time.

Successability: Number of response / numbers of request messages.

Reliability: Ratio of the number of error messages to total messages.

Latency: Time taken for the server to process a given request.

RSCS: response time of customer services.

Cost: the amount or equivalent paid or charged for the cloud service provider.

4.1.2 Provider Assessment

The second step in the methodology is provider identification. In this step, the methodology uses the data after imputation from the modified GAN as mentioned in Table 1. In Table 1, the first column refers to the names of providers for the case study, and row 1 refers to the criteria in the case study.

4.1.3 Linguistics Terms

This section describes each linguistics term and the neutrosophic set according to experts' opinions. The mapping between linguistic terms and the neutrosophic set is shown in Table 2.

4.1.4 Creation of DM

The cloud experts use their knowledge to make the DM according to the linguistic terms they have defined in Table 2. The DM for five cloud service providers and eight criteria by the linguistic opinions of experts is shown in Table 3.

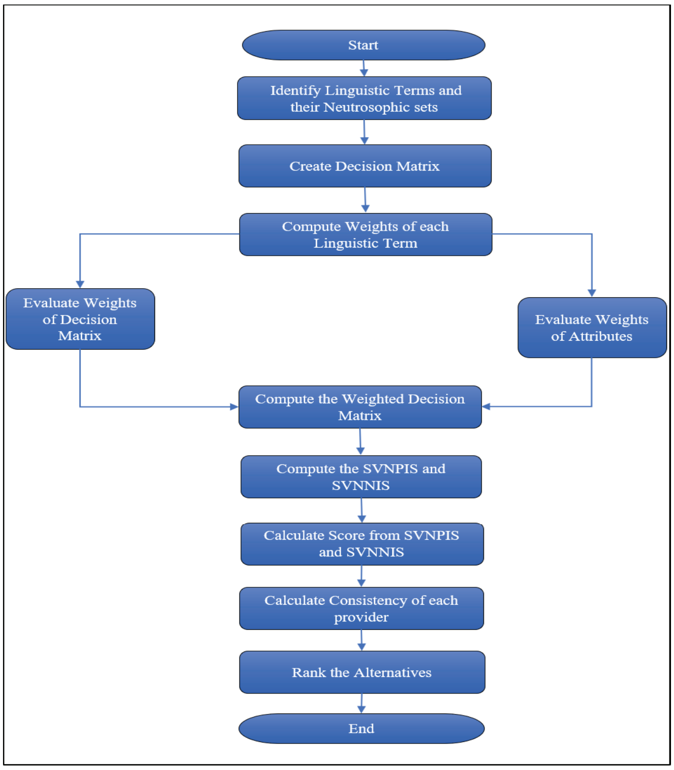

Fig. 3: Flowchart of the Neutrosophic Algorithm

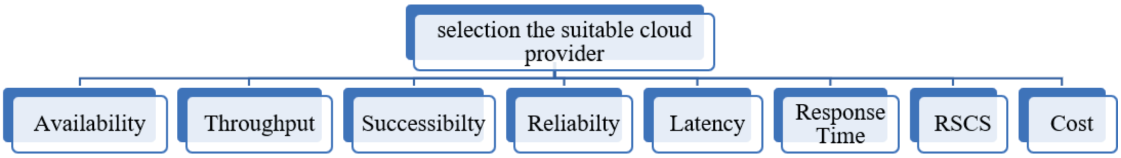

Fig. 4: Hierarchy of providers criteria

Table 1: providers table and criteria.

Cloud Provider	Availability (%)	Throughput (invokes/sec)	Successability (%)	Reliability (%)	Latency (ms)	Response Time (ms)	RSCS (ms)	Cost($)
MAPPMatching	89	7	90	73	104	303	97	30
Compound2	85	16	95	73	1	482	96	21
USDAData	89	1	96	73	2	659	181	29
GBNIRHolidayDates	98	12	100	67	22	126	15	46
CasUsers	87	2	95	73	58	35	35	26

4.1.5 Determination of criteria weights

According to personal interests, organizational needs, or the advice of cloud professionals, cloud users rank the importance of each of the eight criteria. The weights of each criteria provided by the cloud user are shown in Table 4.

4.1.6 Conversion of DM and weights of criteria to neutrosophic sets

This section describes how to transform DM and criteria weights into neutrosophic DM and neutrosophic weights using the mapping function displayed in Table 2. Each language expression is transformed to the corresponding neutrosophic value. The priority assigned to the linguistic phrase by the cloud user is then transformed into a neutrosophic value and displayed in Table 6.

Table 2: Linguistics terms and neutrosophic set.

Linguistic	Term	Neutrosophic Set
Absolutely Good	AG	$< 0.98, 0.01, 0.98 >$
Very Good	VG	$< 0.90, 0.60, 0.92 >$
Good	G	$< 0.80, 0.65, 0.86 >$
Medium-Good	MG	$< 0.75, 0.60, 0.82 >$
Average	AV	$< 0.50, 0.50, 0.92 >$
Medium-Bad	MB	$< 0.60, 0.70, 0.79 >$
Bad	B	$< 0.70, 0.80, 0.88 >$
Very Bad	VB	$< 0.60, 0.90, 0.92 >$
Absolutely Bad	AB	$< 0.01, 0.98, 0.98 >$

4.1.7 Computation of weighted DM

Using Equation 1, the product of neutrosophic DM and neutrosophic criteria weights provides the weighted DM. The creation procedure in a neutrosophic environment to compute the (T,I,F) values of a weighted DM element is illustrated in Equation 17. In Table 7, the weighted DM is displayed.

4.1.8 Establishing of SVNNIS and SVNPIS

Cost-benefit analysis is used to calculate the (SVNPIS) and (SVNNIS). The best and worst options are SVNPIS and SVNNIS. Equation 19 and 20 are used to calculate the SVNPIS and SVNNIS, respectively. Table 8 displays the computed values for SVNNIS and SVNPIS.

4.1.9 Calculate the Score of the alternatives from SVNPIS and SVNNIS

The score the alternatives from SVNPIS and SVNNIS is calculated using Equations 21 and 22, when $V^+ = 1$ or $V^- = 1$ and results are shown in Table 9.

4.1.10 Determination of Consistency of each Cloud Provider and Ranking

Each cloud service provider's consistency is calculated using Equation 23 and its value is displayed in Table 9 Finally, the cloud service providers are evaluated according to the importance of consistency. The cloud service provider with the highest consistency score is rated first, and the one with the lowest score is ranked last. According to the case study, "GBNIRHolidayDates" is ranked highest among cloud service providers, whereas "MAPPMatching" is ranked lowest. Depending on how important the user-provided criteria factors are. the cloud provider's rankings are GBNIRHolidayDates, USDAData, CasUsers, Compound2, and MAPPMatching.

4.2 Comparison and Computational Time

The effectiveness of the suggested framework is measured against various multi-criteria decision-making techniques that are currently accessible, including (AHP, TOPSIS, and VIKOR Neutrosophic). The experiment was conducted on a computer with a 1.1GHz Intel i5-1035G4 10th Gen, 16 GB of RAM, and Windows 10 64-bit installed, and it was successful in achieving high performance in a short amount of time, especially with the numerous providers. The study was conducted using 1507 providers and the eight criteria listed in Table 1. The implementation of Algorithm 1. helps to reduce the computational time because it performs Equation 21. and Equation 22. if and only if $V^+ = 1$ or $V^- = 1$ that leads to decreasing steps of the algorithm. First, we evaluated the framework using 100 cloud service providers and recorded the computation time. Next, we gradually increased the number of providers while recording the computation time for each iteration.In Tables 10, 11, the suggested framework's computation time is contrasted with that of a number of multi-criteria decision-making techniques, including AHP, TOPSIS, and VIKOR Neutrosophic. And Fig. 5 compares them side by side. Figure 5 illustrates that the computation time of the presented model is better than other previous methods with 0.05 (sec) rather than 0.057 (sec), 0.061 (sec), and 0.065 (sec) for Vikor Neutrosphic, TOPSIS, and AHP, respectively.

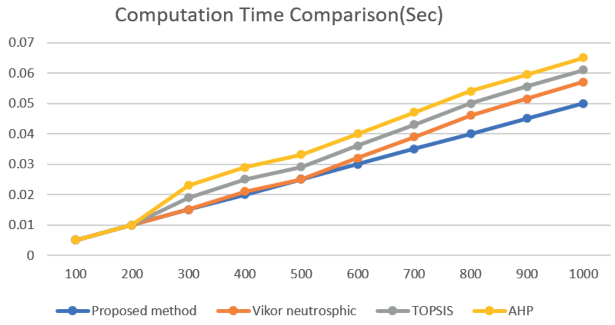

Fig. 5: Comparison chart between the proposed method and other methods

5 Conclusions

The selection of cloud service providers is one of the most significant problems for any company intending to transfer its work to cloud architectures for a variety of properties. This paper presents a novel framework based on modified neutrosophic algorithm to select the best

Table 3: DM with linguistics term.

Cloud Provider	Availability%	Throughput	Successability %	Reliability %	Latency ms	Response Time ms	RSCS	Cost
MAPPMatching	AG	G	VB	AB	B	G	VG	AG
Compound2	MG	AG	B	AV	AB	VG	AG	G
USDAData	AB	B	AG	MB	G	AV	AV	VG
GBNIRHolidayDates	B	AV	G	AB	AG	MB	MB	VB
CasUsers	VB	VG	AG	MB	AV	G	G	VG

Table 4: weights of criteria.

Criteria	Availability%	Throughput	Successability %	Reliability %	Latency ms	Response Time ms	RSCS	Cost
Weight	G	AV	VB	B	VG	G	B	AV

Table 5: DM with linguistics term.

Cloud Provider	Availability%	Throughput	Successability %	Reliability %	Latency ms	Response Time ms	RSCS	Cost
MAPPMatching	<0.98,0.01,0.98>	<0.80,0.65,0.86>	<0.60,0.90,0.92>	<0.01,0.98,0.98>	<0.70,0.80,0.88>	<0.80,0.65,0.86>	<0.90,0.60,0.92>	<0.98,0.01,0.98>
Compound2	<0.75,0.60,0.82>	<0.98,0.01,0.98>	<0.70,0.80,0.88>	<0.50,0.50,0.62>	<0.01,0.98,0.98>	<0.90,0.60,0.92>	<0.98,0.01,0.98>	<0.80,0.65,0.86>
USDAData	<0.01,0.01,0.98>	<0.70,0.80,0.88>	<0.98,0.01,0.98>	<0.60,0.70,0.97>	<0.80,0.65,0.86>	<0.60,0.90,0.92>	<0.50,0.50,0.62>	<0.90,0.60,0.92>
GBNIRHolidayDates	<0.70,0.80,0.88>	<0.50,0.50,0.62>	<0.80,0.65,0.86>	<0.01,0.98,0.98>	<0.98,0.01,0.98>	<0.90,0.60,0.92>	<0.60,0.70,0.79>	<0.60,0.90,0.92>
CasUsers	<0.60,0.90,0.92>	<0.90,0.60,0.92>	<0.98,0.01,0.98>	<0.60,0.70,0.79>	<0.50,0.50,0.62>	<0.60,0.90,0.92>	<0.80,0.65,0.86>	<0.90,0.60,0.92>

Table 6: weights of criteria.

Criteria	Availability%	Throughput	Successability %	Reliability %	Latency ms	Response Time ms	RSCS	Cost
Weight	<0.80,0.65,0.86>	<0.50,0.50,0.62>	<0.60,0.90,0.92>	<0.70,0.80,0.88>	<0.90,0.60,0.92>	<0.80,0.65,0.86>	<0.70,0.80,0.88>	<0.50,0.50,0.62>

Table 7: Weighted neutrosophic DM.

Cloud Provider	Availability%	Throughput	Successability %	Reliability %	Latency ms	Response Time ms	RSCS	Cost
MAPPMatching	<0.784,0.01,0.98>	<0.80,0.65,0.86>	<0.60,0.90,0.92>	<0.01,0.98,0.98>	<0.70,0.80,0.88>	<0.80,0.65,0.86>	<0.90,0.60,0.92>	<0.98,0.01,0.98>
Compound2	<0.75,0.60,0.82>	<0.98,0.01,0.98>	<0.70,0.80,0.88>	<0.50,0.50,0.62>	<0.01,0.98,0.98>	<0.90,0.60,0.92>	<0.98,0.01,0.98>	<0.80,0.65,0.86>
USDAData	<0.01,0.01,0.98>	<0.70,0.80,0.88>	<0.98,0.01,0.98>	<0.60,0.70,0.97>	<0.80,0.65,0.86>	<0.60,0.90,0.92>	<0.50,0.50,0.62>	<0.90,0.60,0.92>
GBNIRHolidayDates	<0.70,0.80,0.88>	<0.50,0.50,0.62>	<0.80,0.65,0.86>	<0.01,0.98,0.98>	<0.98,0.01,0.98>	<0.90,0.60,0.92>	<0.60,0.70,0.79>	<0.60,0.90,0.92>
CasUsers	<0.60,0.90,0.92>	<0.90,0.60,0.92>	<0.98,0.01,0.98>	<0.60,0.70,0.79>	<0.50,0.50,0.62>	<0.60,0.90,0.92>	<0.80,0.65,0.86>	<0.90,0.60,0.92>

Table 8: SVNPIS and SVNNIS values

	Availability%	Throughput	Successability %	Reliability %	Latency ms	Response Time ms	RSCS	Cost
SVNPIS	<1,0,0>	<1,0,0>	<1,0,0>	<1,0,0>	<0,1,1>	<0,1,1>	<0,1,1>	<0,1,1>
SVNNIS	<0,1,1>	<0,1,1>	<0,1,1>	<0,1,1>	<1,0,0>	<1,0,0>	<1,0,0>	<1,0,0>

Table 9: ranking table

Cloud Provider	S+	S-	Consistency %	Rank
MAPPMatching	8.7271	9.7897	52.86928627	2
Compound2	9.2706	8.972	49.18158596	5
USDAData	8.7926	9.6588	52.34724736	3
GBNIRHolidayDates	8.5826	9.7882	53.28129423	1
CasUsers	9.3442	9.4776	50.35437631	4

Table 10: Comparison of the proposed framework with other methods

Method name	Rank robustness	Fuzzy capability
Proposed method	Yes	Yes
Vikor neutrosophic [69]	Yes	Yes
TOPSIS [70]	No	No
AHP [71]	No	NO

suitable provider for any stakeholder. The framework can impute the problem of missing values during data gathering using a modified version of GAN and then rank the providers after completing the data according to the organization's needs. The experiments have proved the efficiency and accuracy of the framework in both imputations of the missing data and in selecting suitable providers. Compared to previous ways, the suggested method takes less time. especially when using large numbers of providers. The computation time for 1000 providers using the proposed model was 0.05 (sec), as opposed to 0.057 (sec), 0.061 (sec), and 0.065 (sec) in other comparable publications. The suggested framework can be strengthened in subsequent work by incorporating group decision making when selecting a cloud service and by combining it with other MCDM techniques. It can

Table 11: Computational Time Table

No. Of Providers	Proposed method (sec)	Vikor Neutrosphic(sec) [69]	TOPSIS (sec) [70]	AHP (sec) [71]
100	0.005	0.005	0.005	0.005
200	0.01	0.01	0.01	0.01
300	0.015	0.015	0.019	0.023
400	0.02	0.021	0.025	0.029
500	0.025	0.0251	0.0291	0.0331
600	0.03	0.032	0.036	0.04
700	0.035	0.039	0.043	0.047
800	0.04	0.046	0.05	0.054
900	0.045	0.0515	0.0555	0.0595
1000	0.05	0.057	0.061	0.065

also be integrated with rough set theory or expanded to an interval-valued neutrosophic set in order to better address.

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