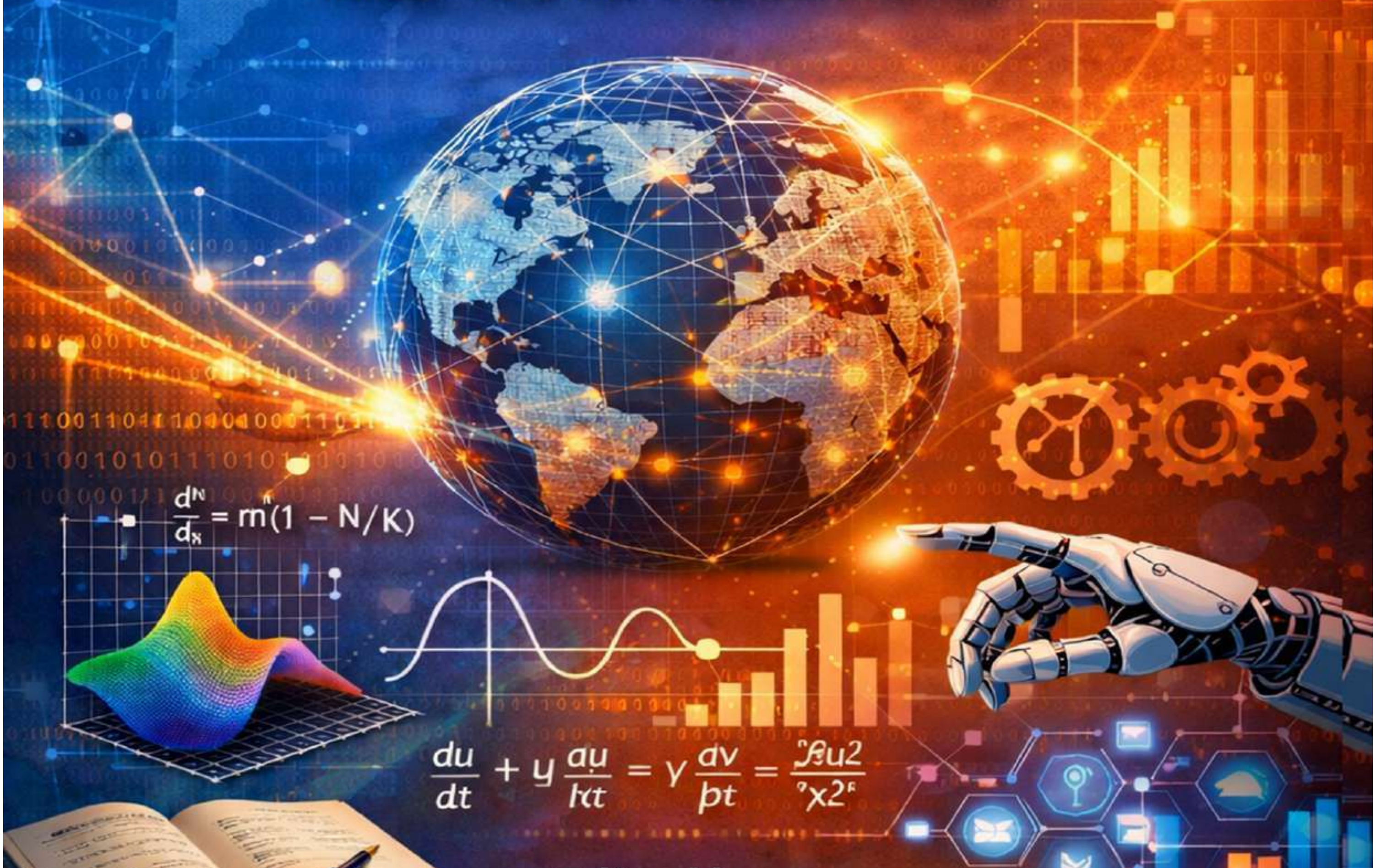
MATHEMATICAL MODELING

AND ITS APPLICATIONS



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6. Mathematical Modelling in Decision-Making Problems using Neutrosophy

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Abstract.

The effectiveness of traditional probabilistic and fuzzy modeling approaches is limited by the uncertainty, incompleteness and inconsistency of information that frequently define real-life decision-making situations. Traditional mathematical frameworks are unable to accurately capture the conflicting information, missing data and ambiguous expert opinions that decision-makers encounter in real-world scenarios. Neutrosophic set theory offers a versatile and practical method for simulating such intricate systems by introducing independent truth, indeterminacy and falsity membership functions. Examples are used in this research to demonstrate the applicability of a Neutrosophic Mathematical Modeling framework for real-life issues. The suggested models show how uncertainty, contradiction and indeterminacy can be captured by Neutrosophic aggregation techniques, resulting in more trustworthy and instructive decision-support systems.

Keywords: Neutrosophic sets, Decision-making, Uncertainty Modelling, Indeterminacy.

1.Introduction

Real-world systems rarely make decisions based on accurate, consistent and comprehensive information. Decisions in domains including supply chain management, engineering and healthcare frequently have to be made in the face of ambiguous information. opposing expert opinions and uncertainty. The main focus of classical probabilistic methods is randomness whereas fuzzy set theory uses partial membership to explain vagueness. The capacity of both frameworks to clearly depict indeterminacy brought on by omitted data or conflicting evidence is constrained, nevertheless. In order to get around these restrictions, Smarandache developed Neutrosophic set theory, which adds three membership degrees-truth, indeterminacy and falsity to fuzzy and intuitionistic fuzzy frameworks. Because of their independence, Neutrosophic models are able to depict ambiguity, rejection and acceptance all at once without being constrained.

The objective of this study is to formulate real-life decision-making problems using a Neutrosophic Mathematical framework and to demonstrate its effectiveness through real-life problems. As a result, Neutrosophic Modelling has gained increasing attention in its applications. Because of their significant decision effect, inherent uncertainty and dependence on expert judgement, these following areas have been chosen. In this study, the basic concepts and details can be found in [1-20].

2.Neutrosophic Modelling framework

In Neutrosophic Set Theory, each element is characterized by a triple (T, I, F) where T, I and F denote the degrees of truth, indeterminacy and falsity respectively. These values belong to the interval [0,1] and satisfy the condition $0 \le T+I+F \le 3$. The degree to which the available evidence supports a particular decision in real-life decision-making contexts is represented by the truth membership; the degree to which opposing evidence leads to a decision being rejected is represented by the falsity membership and the uncertainty resulting from conflicting, ambiguous or incomplete information is captured by the indeterminacy membership. Compared to traditional or fuzzy-based methods, this framework enables decision-makers to model uncertainty more accurately. Weighted Neutrosophic operators are frequently used for aggregation. The overall truth, indeterminacy and falsity values are determined by independently aggregating the corresponding components using weighted summation or other appropriate operators, given a set of criteria with corresponding weights.

3. Neutrosophic Model for Medical Diagnosis

Uncertainty, incompleteness, and inconsistent information are characteristics of the difficult real-world problem of medical diagnosis. Medical professionals rely on symptoms, clinical observations, and laboratory tests that may be inconsistent, imprecise, or only partially available. Indeterminacy resulting from missing data, divergent expert judgments, or incorrect test findings is not clearly represented by traditional probabilistic and fuzzy techniques, which primarily capture uncertainty. A more practical mathematical framework for simulating these diagnostic issues is offered by neutrophilic set theory. Think about a medical diagnosis situation where a doctor wants to know if a patient has a particular illness, like pneumonia. A limited number of clinical tests and symptoms, such as fever, cough, chest pain, and chest X-ray results, are used to make the diagnosis.

A Neutrosophic assessment is used to illustrate the connection between each symptom and the illness. For every symptom is characterized by a triple (T, I, F) where T, I and F denote the degrees of truth, indeterminacy and falsity respectively. The overall disease assessment for a patient is obtained by aggregating all symptom evaluations using a weighted summation approach. The resulting neutrosophic diagnosis may take the form $(T, I, F) = (0.66, 0.22, 0.12)$.

Medical information particular to a patient is sometimes ambiguous because symptoms can change or be subjectively reported. Neutrosophic values, as opposed to clear-cut or binary representations, are a natural way to express this uncertainty. A weighted summation approach is used to aggregate all symptom evaluations in order to determine the patient's overall disease assessment. showing comparatively little evidence against the diagnosis, moderate indeterminacy brought on by ambiguous material, and significant evidence non favor of the illness. This finding gives physicians a thorough grasp of the disease's probability as well as the uncertainty that goes along with it.

4. Neutrosophic Model for Supplier Selection

In supply chain management, choosing a supplier is a crucial decision-making issue that has an immediate impact on the price, dependability, and quality of production systems. In real-world settings, subjective assessments, contradictory expert opinions, and insufficient data are frequently used to evaluate supplier evaluation criteria such product quality, delivery performance, cost stability, and technological capabilities. Such intricacy cannot be handled by traditional probabilistic or sharp models. Each evaluation criterion in a neutrosophic framework is represented by a single-valued neutrosophic number that has membership degrees for truth, indeterminacy, and falsity. The degree of failure is represented by the falsehood membership, the degree of truth membership indicates how well a supplier meets a requirement, and the indeterminacy membership depicts the uncertainty brought on by incomplete or erratic information.

Imagine a manufacturing company comparing several suppliers using weighted factors such product quality, cost effectiveness, delivery dependability, and after-sales support. Experts offer a neutrosophic evaluation to each supplier and criterion, (T_{ij}, I_{ij}, F_{ij}) where i is the criterion and j is the provider, where i is the supplier and j is the threshold. Weighted summation is used to combine these assessments to provide an overall neutrosophic score.

A numerical assessment could show, for example, (0.62,0.25,0.13) that the provider performed satisfactorily with minimal rejection and moderate uncertainty. Decision-makers can differentiate between suppliers with comparable performance levels but distinct risk and uncertainty profiles thanks to this representation.

5.Neutrosophic Model for Engineering Risk Assessment

Bridges, power plants, and industrial gear are examples of engineering systems that function in dynamic, uncertain environments with little access to comprehensive and trustworthy data. In such systems, risk assessment is dependent on a number of variables, including as human operation, maintenance quality, ambient conditions, and material strength, all of which can include inaccurate measurements and divergent expert opinions. In practice, it might be challenging to determine the precise failure probability needed for probabilistic risk models and classical reliability theory. By directly representing uncertainty and indeterminacy in engineering risk analysis, neutrophilic set theory offers a useful substitute.

A triple represents each risk factor in a Neutrosophic framework, (T_j, I_j, F_j) Whereas the indeterminacy membership accounts for uncertainty brought on by inadequate inspection data, measurement errors, or expert disagreement, the truth membership indicates the extent to which the factor contributes to system safety, and the falsity membership indicates the extent to which it contributes to system failure. For instance, a structural component's corrosion may be a partial indicator of failure risk, but indeterminacy is increased by restricted inspection access. Think about an engineering system that is assessed according to elements like maintenance history, environmental exposure, load intensity, and material condition. Every component is given a weight that corresponds to its proportional significance for system safety as a

whole.A weighted summation method is used to aggregate the neutrosophic ratings of all risk categories, yieldin g an overall system reliability score that is stated as *(T, I, F).*

A numerical assessment such as (0.58,0.27,0.15) shows that although the system is reasonably safe, there is a considerable amount of uncertainty that might necessitate additional testing or preventative maintenance. When indeterminacy is present, engineers are made aware of possible hidden hazards that conventional binary or probabilistic models are unable to account for. As a result, neutrosophic risk evaluation facilitates more cautious and knowledgeable engineering choices.

6.Neutrosophic Model for Environmental Pollution Assessment

Another real-world issue that is marked by ambiguity, insufficient monitoring data, and conflicting expert opinions is the assessment of environmental contamination. Numerous interrelated elements, including traffic density, industrial emissions, weather, and law enforcement, affect pollution levels. For trustworthy environmental decision-making, traditional deterministic or probabilistic models are insufficient since measurements may be absent, delayed, or impacted by sensor errors.

Every pollution indicator in Neutrosophic environmental modelling is represented by a Neutrosophic triple (T_i, I_i, F_i) where the indeterminacy membership denotes uncertainty brought on by missing data, seasonal variations, or contradicting reports from monitoring agencies, the truth membership denotes the degree to which the indicator confirms environmental pollution, and the falsity membership denotes the degree to which pollution is absent or controlled.

Take an environmental agency evaluating the quality of the air in a city using metrics like nitrogen dioxide levels, particulate matter concentrations, industrial activity, and weather patterns. The environmental impact of each indication determines its weight. An overall pollution assessment is produced by the Neutrosophic aggregation of all indicators, and it is stated as *(T, I, F).* The evaluation such as (0.58,0.27,0.15) indicates a high level of pollution with a moderate degree of uncertainty, recognizing the limitations in the accuracy of the data while pointing to the urgent need for regulatory action. The Neutrosophic model, in contrast to traditional pollution indices, clearly measures uncertainty, allowing policymakers to create more flexible and cautious environmental management plans.

7.Neutrosophic Model for Financial Credit Risk Assessment

In banking and financial institutions, where judgments about loan acceptance are based on ambiguous, partial, and occasionally conflicting information, credit risk assessment is a basic issue. Many times, historical data that may be shaky or out-of-date is used to assess factors including market conditions, employment status, credit history, and income stability. Such indeterminacy is difficult for traditional statistical and probabilistic credit scoring algorithms to manage, especially in unstable economic conditions. To overcome these restrictions, neutrophilic set theory offers an appropriate mathematical foundation.

Each risk factor is represented by a Neutrosophic triple in a Neutrosophic credit risk model as (T_i, I_i, F_i) where the indeterminacy membership reflects uncertainty resulting from missing financial records or unstable revenue sources, the truth membership represents the degree to which the factor promotes creditworthiness, and the falsity membership represents the degree to which it suggests default risk. A borrower with inconsistent freelancing income, for instance, can exhibit both credit potential and repayment uncertainty. Each risk element is given a weight that corresponds to its significance in assessing credit, *(T, I, F).* Using the combined Neutrosophic evaluation, an overall borrower profile is produced. The numerical outcome as (0.55,0.30,0.15) shows considerable uncertainty and moderate creditworthiness, indicating the necessity for extra assurances or modified interest rates. Compared to traditional scoring methods, this Neutrosophic depiction gives institutions a more sophisticated understanding of credit risk.

8.Neutrosophic Model for Student Performance Evaluation

A difficult educational decision-making issue, evaluating student performance is impacted by behaviour, extracurricular activities, academic accomplishment, and attendance. These factors, which may include inaccurate or contradictory information, are frequently evaluated subjectively by teachers. Uncertainty pertaining to learning progress, individual difficulties, or evaluation bias is not captured by conventional grading schemes. For evaluating education, neutrophilic modeming provides a more adaptable framework.

This model uses a Neutrosophic triple to represent each assessment criterion as (T_i, I_i, F_i) where the indeterminacy membership depicts uncertainty brought on by sporadic attendance, incomplete assessments, or subjective evaluation, the truth membership indicates academic competency, and the falsehood membership represents subpar performance. A weight is given to each criterion according to its academic significance. When these assessments are combined, a comprehensive evaluation of Neutrosophic performance is generated as (T, I, F) that indicates a high level of academic achievement with a modest degree of ambiguity. Instead of imposing strict classifications, this method recognizes the outcome such as (0.68,0.21,0.11) uncertainty publicly, which promotes more equitable academic decisions.

9.Neutrosophic Model for traffic congestion Analysis

Road capacity, traffic volume, weather, accidents, and driver behaviour all have an impact on urban traffic congestion, which is a dynamic and unpredictable issue. Sensor limitations and unforeseen events might cause traffic data to be inconsistent, delayed, or incomplete. Such indeterminacy is frequently not adequately represented by traditional deterministic or simulation-based models. A realistic foundation for the examination of traffic congestion is offered by neutrophilic modelling.

A Neutrosophic evaluation is used to represent each congestion-related factor as (T_i, I_i, F_i) When the indeterminacy membership captures the uncertainty brought on by unforeseen events or faulty data, the truth membership indicates the level of congestion, and the falsity membership depicts free-flowing traffic circumstances. When these elements are weighted together, the overall level of congestion is stated as (T, I, F). A result such as (0.74,0.18,0.08) shows extreme traffic with little room for doubt, directing traffic officials to take prompt action. Adaptive traffic management tactics are made possible by the Neutrosophic model, which takes uncertain real-time information into consideration.

10.Conclusion

The practical application and wide-ranging applicability of Neutrosophic set theory as a cohesive mathematical framework for simulating real-world decision-making situations that are marked by ambiguity, incompleteness, and inconsistency have been shown by this study. The versatility of Neutrosophic modelling has been demonstrated through a wide range of case studies, such as agricultural crop yield prediction, medical diagnosis, supplier selection, engineering risk assessment, environmental pollution evaluation, financial credit risk analysis, student performance evaluation, traffic congestion analysis, disaster risk management, smart grid energy management, cybersecurity threat assessment, customer satisfaction analysis, and human resource recruitment.

When compared to classical, fuzzy, and intuitionistic fuzzy models, the Neutrosophic representation employing independent truth, indeterminacy, and falsity membership degrees consistently produced richer and more insightful decision outputs.

Neutrosophic models assess uncertainty, negative evidence, and positive evidence all at once, in contrast to traditional methods that frequently reduce complex circumstances to a single score or likelihood. In real-world situations where data may be lacking, expert opinions may differ, and system behaviour may be unpredictable, this skill proved crucial. While maintaining the intrinsic uncertainty of each contributing element, the aggregation procedures used in the models that were presented allowed for the consistent and visible integration of many criteria. By clearly indicating the need for further information when indeterminacy was significant, this promoted safer and more cautious decision-making in engineering and medical applications. By differentiating between risk, uncertainty, and performance, Neutrosophic evaluations enabled better balanced decisions in managerial, financial, and social systems.

All things considered, the comparative study of every example demonstrates that Neutrosophic modelling provides a strong, adaptable, and domain-independent method for real-world decision-support systems. It is especially appropriate for contemporary complex systems since it can manage ambiguity, contradiction, and indeterminacy within a single mathematical framework. To increase the usefulness of Neutrosophic decision-making approaches, future studies might concentrate on creating dynamic Neutrosophic models, hybrid frameworks that incorporate machine learning methods, and large-scale computing implementations.

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