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Current Situation of the Integration of Neutrosophy in Requirements Engineering

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Abstract: This study conducts a comprehensive literature review to explore the integration of neutrosophic logic in Requirements Engineering (RE), addressing challenges such as uncertainty, ambiguity, and conflicting stakeholder perspectives. By systematically analyzing peer-reviewed studies from 2015 to 2024, the research synthesizes existing neutrosophic techniques—including Type-2 Neutrosophic Numbers (T2NNs), Neutrosophic Cognitive Maps (NCMs), and Single-Valued Neutrosophic Sets (SVNS)—and categorizes their applications into uncertainty handling, conflict resolution, and requirement prioritization. The study highlights neutrosophy's transformative potential in enhancing RE practices, offering robust solutions beyond traditional methods. Additionally, it identifies underexplored techniques like Bipolar Neutrosophic Sets (BNS) and Neutrosophic Rough Sets (NRS) for future research, underscoring neutrosophy's role as a paradigm shift in managing RE complexities.

Keywords: Neutrosophy, Requirements Engineering, uncertainty handling, conflict resolution, requirement prioritization, neutrosophic techniques.

1. Introduction

Requirements Engineering (RE) is a critical phase in software development, where the needs and constraints of stakeholders are identified, analyzed, and documented [1, 2]. However, RE often grapples with inherent challenges such as uncertainty, ambiguity, and conflicting stakeholder perspectives, which traditional methods struggle to address effectively [3]. These challenges can lead to misinterpretations [4], incomplete specifications, and ultimately, project failures [5].

Neutrosophy [6], a generalization of fuzzy logic and intuitionistic fuzzy sets, introduces the concept of truth (T), indeterminacy (I), and falsity (F) degrees, providing a robust framework to model and manage uncertainty, subjectivity, and conflicts in RE. By leveraging neutrosophic logic and its extensions, such as Neutrosophic Cognitive Maps (NCMs) [7] and Single- Valued Neutrosophic Sets (SVNS) [8], researchers have begun to explore innovative solutions for handling vague requirements, resolving stakeholder conflicts, and prioritizing features more effectively [9, 10].

Despite these advancements, the integration of neutrosophy into RE remains an emerging field, with scattered applications and limited systematic reviews. This study aims to bridge this gap by conducting a comprehensive literature review to:

1. Synthesize existing neutrosophic techniques applied in RE, categorizing them into key areas like uncertainty handling, conflict resolution, and prioritization.
2. Evaluate the transformative potential of neutrosophy in addressing RE challenges, highlighting its advantages over traditional methods.
3. Identify underexplored neutrosophic techniques (e.g., Bipolar Neutrosophic Sets, Neutrosophic Rough Sets) that could further enhance RE practices.

By systematically analyzing peer-reviewed studies from 2015 to 2024, this work not only maps the current landscape of neutrosophy in RE but also motivates future research to expand its applications, ensuring more resilient and adaptive software development processes. The findings underscore neutrosophy's role as a paradigm shift in managing the complexities of modern RE.

1. Methodology

To conduct a comprehensive literature review on the integration of neutrosophy in Requirements Engineering (RE) we applied the following steps.

1.1. Search Strategy and Data Sources

Articles were systematically searched and extracted from multiple academic databases, including Scopus, Google Scholar, IEEE Xplore, and SpringerLink. The search was performed using the following keywords:

- "Neutrosophy AND Requirements Engineering"
- "Neutrosophic logic AND software requirements"
- "Neutrosophic sets AND uncertainty in RE"
- "Neutrosophic techniques AND conflict resolution in RE"

1.2. Search Criteria

- Timeframe: Articles published between 2015 and 2024 were prioritized to ensure relevance to current advancements.
- Language: Only English-language publications were considered.
- Publication Type: Peer-reviewed journal articles, conference papers, and book chapters were included.

1.3. Inclusion and Exclusion Criteria

Inclusion Criteria:

- Studies explicitly applying neutrosophic logic/sets to RE challenges (e.g., uncertainty, conflict resolution, prioritization).
- Empirical or theoretical contributions with clear methodologies.
- Articles directly addressing the three focus areas identified in the manuscript: uncertainty handling, conflict resolution, and prioritization.

Exclusion Criteria:

- Duplicate studies or redundant publications.
- Articles lacking technical depth (e.g., short abstracts, opinion pieces).
- Studies not peer-reviewed or with unclear methodologies.
- Works focused solely on traditional fuzzy logic without neutrosophic extensions.

1.4. Article Selection Process

- Initial Screening: 25 articles were identified from databases based on keywords and abstracts.
- Full-Text Review: 15 articles were evaluated for relevance and methodological rigor.

- Final Selection: 8 articles met all inclusion criteria and were included in the review.

1.5. Reasons for Exclusion

- 7 articles were excluded for irrelevance (e.g., applied fuzzy logic but not neutrosophy).
- 5 articles were rejected due to methodological flaws (e.g., insufficient validation or unclear neutrosophic techniques).
- 3 articles were duplicates or superseded by more recent studies.
- 2 articles were excluded for language barriers (non-English publications).

1.6. Final Dataset

The 8 selected articles (cited as [7, 8, 11–16] in the manuscript) were categorized into three application areas (Table 1) and analyzed for their neutrosophic techniques (Table 2). This structured approach ensured a focused review of high-impact, relevant studies while maintaining methodological transparency.

1.7. Limitations

- Potential bias from database selection (e.g., Scopus-indexed journals favored).
- Exclusion of non-English studies may overlook regional contributions.

This methodology aligns with PRISMA guidelines for systematic reviews, ensuring repro- ducibility and rigor in synthesizing neutrosophy's role in RE.

2. Results

In this section, we highlight the transformative potential of neutrosophy in addressing key challenges in Requirements Engineering (RE). By leveraging neutrosophic logic—which incorporates truth (T), indeterminacy (I), and falsity (F) degrees— this review of the literature collects innovative solutions for (1) Handling Uncertainty in Requirements, where vague or incomplete stakeholder inputs are modeled with precision; (2) Conflict Resolution Among Stakeholders, where neutral influences help reconcile contradictory needs; and (3) Requirement Prioritization. Table 1 categorizes these applications.

Table 1. Categorizing Neutrosophy Applications in Requirement Engineering.

Category	Papers
Handling Uncertainty in Requirements	[11], [12], [13], [7], [8], [16]
Conflict Resolution Among Stakeholders	[13], [14]
Requirement Prioritization	[11], [15], [8], [16]

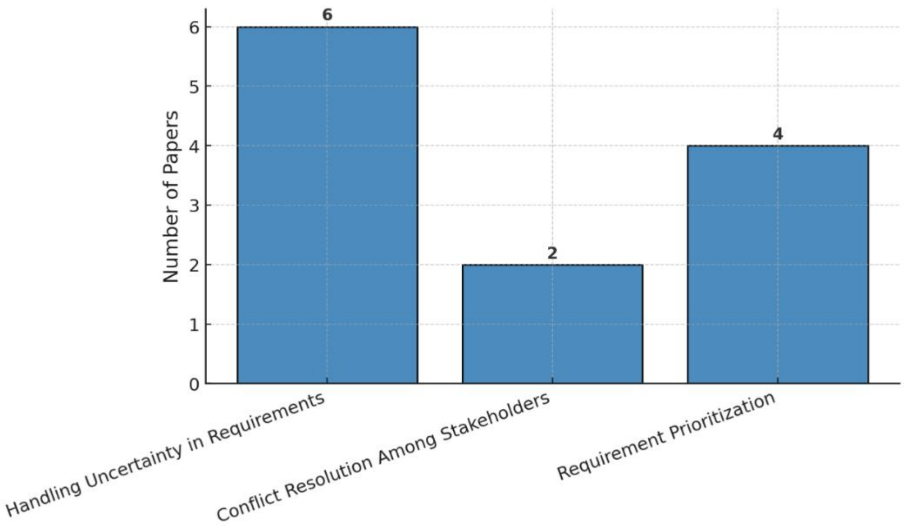

Figure 1. Categorization of Neutrosophy Applications in Requirement Engineering

Handling Uncertainty in Requirements

Traditional RE struggles with imprecise, incomplete, or conflicting stakeholder inputs. Neu- trosophic Sets & Logic can model requirements with truth (T), falsity (F), and indeterminacy (I) degrees. For example, a requirement like "The system should respond quickly" can be represented as (T=0.7, I=0.2, F=0.1), meaning it is mostly true but has some ambiguity. Below, we present the neutrosophic techniques that have considered the selected works to handle uncertainty in requirements.

In [11], authors used Type-2 Neutrosophic Numbers (T2NNs) to address vague and imprecise stakeholder judgments in requirements prioritization. In [12], the Interval-Valued Neutrosophic Z-Numbers (NZN) and NZN-Area are used to handle uncertainty and reliability in software development team assignments. In [13], the Interval-Valued Trapezoidal Neutrosophic Sets (IVTrNS) are considered to manage uncertainty and incompleteness in Non-Functional Re- quirements (NFRs). Moreover, [7] applies Neutrosophic Cognitive Maps (NCMs) to handle uncertainty and subjective interdependencies among NFRs in a panic button system. In addition, in [8], the Single-Valued Neutrosophic Sets (SVNS) are used to model human subjectivity and ambiguity in software requirement prioritization. Finally, the work presented in [16] employs Single-Valued Neutrosophic Numbers (SVN numbers) to address indeterminacy and uncertainty in decision-making for requirement prioritization.

2.1. Conflict Resolution Among Stakeholders

Different stakeholders may have contradictory needs. For it, Neutrosophic Cognitive Maps (NCMs) can help to analyze and resolve conflicts by considering neutral (indeterminate) influences. For example, if two stakeholders disagree on a feature priority, neutrosophic reasoning can find a compromise by accounting for partial acceptance and uncertainty. Below, we present the neutrosophic techniques that have considered the selected works to handle conflict resolution among stakeholders.

The work published in [13] focuses on resolving conflicts among Non-Functional Requirements (NFRs) by addressing uncertainty and incompleteness in stakeholder preferences. Another work [14] uses Neutrosophic Cognitive Maps (NCMs) to model and analyze interdependencies between NFRs, capturing expert knowledge and resolving conflicts.

2.2. Requirement Prioritization

In software engineering and project management, requirement prioritization is the process of ranking requirements based on their importance, urgency, feasibility, and business value. This helps in efficient resource allocation, managing stakeholder expectations, delivering high-value features early, and reducing project risks. Below, we present the neutrosophic techniques that have considered the selected works to handle requirement Prioritization.

The work presented by [11] proposes a framework for prioritizing software requirements using T2NNs combined with DEMATEL and TOPSIS. Moreover, in [15], Neutrosophic Analytic Hierarchy Process (NAHP) is applied to prioritize requirements for a facial recognition system. In addition, the work presented by [8] prioritizes software requirements using Neutrosophic TOPSIS with SVNS. Finally, the work presented in [16] develops a prioritization model for software requirements using SVN numbers and aggregation operators.

3. Discussion

Table 2 showcast how neutrosophic techniques are applied to support the requirement engineering proccess in the selected works. These applications are motivated by the inherent complexities of RE, where traditional approaches often fall short in managing ambiguity, subjectivity, and competing stakeholder interests. The integration of neutrosophy thus offers a robust framework to enhance decision-making and project outcomes in RE.

Table 2. Classification of Neutrosophic Techniques

Neutrosophic Technique	Study
Type-2 Neutrosophic Numbers (T2NNs)	[11]
Interval-Valued Neutrosophic Z-Numbers (NZN)	[12]
Interval-Valued Trapezoidal Neutrosophic Sets	[13]
Neutrosophic Cognitive Maps (NCMs)	[14], [7]
Neutrosophic AHP (NAHP)	[15]
Single-Valued Neutrosophic Sets (SVNS)	[8]
Single-Valued Neutrosophic Numbers (SVN)	[16]

The selected works highlight several neutrosophic techniques applied in Requirements Engi- neering (RE), such as Type-2 Neutrosophic Numbers (T2NNs), Neutrosophic Cognitive Maps (NCMs), and Single-Valued Neutrosophic Sets (SVNS). However, other neutrosophic techniques could also be beneficial for addressing challenges in RE. Below are some techniques not mentioned in the article, along with examples of their potential applications:

- **Bipolar Neutrosophic Sets (BNS)**: It extends neutrosophic sets by incorporating bipolarity (positive and negative aspects) to model conflicting information [17]. It can be applied in conflict resolutions among stakeholders. BNS can represent both supportive and opposing views for a requirement. For example, a requirement like "The system should include a chatbot" could have positive aspects (e.g., improves user experience) and negative aspects (e.g., increases development cost). BNS can quantify these opposing views to facilitate balanced decision-making.
- **Neutrosophic Rough Sets (NRS)**: It integrates rough sets with neutrosophic logic to handle uncertainty and vagueness in incomplete data [18]. For incomplete or am- biguous requirements, NRS can classify requirements into certain, possible, or inde- terminate categories. For instance, a vague requirement like "The system should be user-friendly" can be analyzed to determine its core meaning (certain), potential interpretations (possible), and unclear aspects (indeterminate).
- **Neutrosophic Multi-Criteria Decision Making (NMCDM)**: It extends traditional MCDM methods by incorporating neutrosophic logic to handle uncertainty in criteria weights and evaluations [19]. For selecting the best set of requirements from a pool, NMCDM can evaluate each requirement against criteria like cost, feasibility, and stakeholder value, while accounting for indeterminacy in the evaluations. For instance, a requirement's feasibility might be rated as (T=0.7, I=0.2, F=0.1) due to unclear technical constraints.
- **Neutrosophic Graph Theory (NGT)**: It applies graph theory in a neutrosophic context to model relationships with uncertainty [20]. For modeling dependencies between requirements, NGT can represent relationships like "requires" or "conflicts with" using neutrosophic edges. For example, a dependency between two requirements might be partially true (T=0.6, I=0.3, F=0.1) if their relationship is context dependent.

4. Conclusion

This study systematically reviews the integration of neutrosophic logic in Requirements Engineering (RE), highlighting its transformative potential in addressing key challenges such as uncertainty, ambiguity, and conflicting stakeholder perspectives. By categorizing and analyzing eight peer-reviewed studies, the research demonstrates how neutrosophic techniques—including Type-2 Neutrosophic Numbers (T2NNs), Neutrosophic Cognitive Maps (NCMs), and Single-Valued Neutrosophic Sets (SVNS)—provide robust frameworks for un- certainty handling, conflict resolution, and requirement prioritization. These techniques outperform traditional methods by explicitly modeling truth, indeterminacy, and falsity degrees, enabling more precise and adaptive decision-making in RE.

The study identifies underexplored neutrosophic techniques, such as Bipolar Neutrosophic Sets (BNS) and Neutrosophic Rough Sets (NRS), which hold promise for further enhancing RE practices. Future research should focus on expanding the application of these techniques, particularly in complex, real-world scenarios, to validate their scalability and effectiveness. Additionally, interdisciplinary collaborations could bridge gaps between theory and practice, fostering innovations that align neutrosophic logic with emerging trends in software engineering. By addressing these opportunities, the RE field can achieve greater resilience and adaptability in managing the evolving complexities of modern software

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