NSS

Neutrosophic Sets and Systems, Vol. 99, 2026

University of New Mexico

Fuzzy reliability analysis of a robotic system using single-valued neutrosophic sets based on score, accuracy and certainty functions

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Abstract : In modern engineering systems, uncertainties and incomplete information often pose significant challenges in accurately evaluating system reliability. Traditional probabilistic and fuzzy approaches are insufficient to effectively capture indeterminacy and inconsistency inherent in real-world environments. To address these limitations, this study proposes a neutrosophic framework for fuzzy reliability analysis of a robotic system using single-valued neutrosophic sets (SVNS). In the proposed approach, the reliability of each system component is represented by a neutrosophic triplet characterized by truth, indeterminacy, and falsity membership degrees. A fuzzy success fault tree model is developed to analyze the reliability structure of the robotic system, incorporating both series and parallel configurations of components such as motors, sensors, rollers, and bearings. The overall system reliability is computed using neutrosophic aggregation operators. Furthermore, to ensure a comprehensive and consistent evaluation, three decision-making measures namely score, accuracy, and certainty functions are employed. These functions establish a total order on neutrosophic numbers, enabling complete and unambiguous assessment of system reliability. A numerical example of a robotic system is presented to demonstrate the applicability and effectiveness of the proposed methodology. The results indicate that the neutrosophic-based approach provides a more flexible, robust, and realistic representation of uncertainty compared to conventional fuzzy reliability models. The inclusion of the certainty function enhances the decision-making process by ensuring completeness in ranking and improving the reliability evaluation framework.

Keywords: Single-valued neutrosophic sets (SVNS); Fuzzy reliability; Robotic system; Score function; Accuracy function; Certainty function; Fault tree analysis.

1. Introduction

In [13], Zadeh introduced the concept of fuzzy set theory, which provided a flexible mathematical framework for modeling uncertainty and imprecision in real-world phenomena. Since its inception, fuzzy set theory and fuzzy logic have been successfully applied in numerous domains, including control systems, decision making, pattern recognition, and reliability analysis. Despite its wide applicability, the classical fuzzy set framework cannot fully express the hesitation or lack of complete information that often arises in practical engineering and decision-making environments. To overcome this limitation, [1] proposed the concept of intuitionistic fuzzy sets (IFS), which extend conventional fuzzy sets by incorporating both membership and non-membership degrees. However, intuitionistic fuzzy sets still face limitations when the available information is not only incomplete but also inconsistent or indeterminate, which frequently occurs in complex engineering systems.

To address such higher levels of uncertainty, [8] proposed the theory of neutrosophic sets (NSs), which generalize both fuzzy and intuitionistic fuzzy frameworks by introducing three independent membership functions: truth-membership (T), indeterminacy-membership (I), and falsity-membership (F). Unlike intuitionistic fuzzy sets, neutrosophic sets impose no restriction on the sum of these components, allowing them to vary independently within the interval [0,1]. This flexibility makes neutrosophic theory a powerful tool for handling imprecise, indeterminate, and inconsistent information. Building upon this concept, [11] introduced single-valued neutrosophic sets (SVNS), which provide a practical representation by restricting T, I, and F to real values in [0,1]. Due to their interpretability and mathematical robustness, SVNSs have been widely applied in decision making, image processing, risk analysis, and reliability engineering.

Reliability theory plays a vital role in evaluating the performance and safety of complex engineering systems. It is defined as the probability that a system performs its intended function under specified conditions for a given period of time. However, in real-world applications such as robotics, aerospace systems, and industrial automation, precise reliability data are often unavailable or unreliable due to human judgment, environmental variations, and insufficient testing. In such cases, classical probabilistic models become inadequate, and fuzzy or neutrosophic approaches are required to effectively capture the underlying uncertainty. Several researchers have contributed to the advancement of fuzzy reliability analysis. For instance, [7] proposed a fuzzy fault tree approach, while [2] developed fuzzy reliability theory using possibility measures. [3] introduced fuzzy number-based reliability analysis, and subsequent studies such as [4], [6], and [5] further extended fuzzy reliability modeling for complex systems. Nevertheless, these approaches still face challenges in explicitly handling indeterminacy and inconsistency present in real-life systems.

In neutrosophic-based reliability analysis, system performance is typically represented by neutrosophic triplets of the form (T, I, F). To evaluate and compare such triplets, appropriate decision-making measures are required. Traditionally, score and accuracy functions have been used to assess the overall performance and reliability of neutrosophic numbers. However, the use of only these two functions may lead to ambiguity in cases where different neutrosophic values yield identical score and accuracy measures. To address this limitation, [10] introduced the certainty function, which considers the truth-membership degree as a measure of confidence. The combined use of score, accuracy, and certainty functions establishes a total order on the set of neutrosophic triplets, ensuring a complete and consistent ranking among alternatives. This theoretical advancement enhances the robustness and reliability of decision-making processes under uncertainty.

Motivated by these considerations, the present study proposes a neutrosophic fuzzy framework for evaluating the reliability of a robotic system using single-valued neutrosophic sets. In this approach, the reliability of each component is represented as a neutrosophic triplet to capture truth, indeterminacy, and falsity independently. A fuzzy success fault tree model of the robotic system (FTRS) is developed, where components such as motors, sensors, rollers, and bearings are arranged in series and parallel configurations. The overall system reliability is computed using neutrosophic aggregation operations. Furthermore, to ensure a comprehensive and unambiguous evaluation, the score, accuracy, and certainty functions are employed, thereby aligning the proposed methodology with the total order principle of neutrosophic numbers.

The remainder of this paper is organized as follows. Section 2 presents the basic definitions and concepts related to neutrosophic sets and SVNS. Section 3 discusses the fundamental operations on SVNS, including score, accuracy, and certainty functions. Section 4 develops propositions for reliability evaluation of series and parallel systems. Section 5 describes the robotic system and its fault tree representation along with numerical analysis. Finally, Section 6 concludes the paper with key findings and future research directions.

2. Preliminaries and Basic Definitions

In this section, we present the fundamental concepts and mathematical formulations related to interval-valued neutrosophic sets (IVNSs), which form the theoretical foundation for the proposed reliability analysis. The notion of IVNS extends the classical and intuitionistic fuzzy frameworks by introducing interval-based representations of truth, indeterminacy, and falsity membership functions. This extension enables a more comprehensive and flexible modeling of real-world uncertainty, where information is often incomplete, inconsistent, or vague. For clarity and completeness, some essential definitions, notations, and key operations of interval-valued neutrosophic sets are discussed below.

2.1. *Fuzzy set [13]*

"Let $X = \{x_1, x_2, x_3, ..., x_n\}$ be a universe of discourse, then a fuzzy set A in X is defined as follows:

$$A = \{\langle x, \mu_A(x)\rangle | x \in X\}$$

where $\mu_A(x) : X \to [0,1]$ is the membership degree."

2.2. *Intuitionistic fuzzy set [1]*

"An Atanassov's intuitionistic fuzzy set A in x can be written as:

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle | x \in X\}$$

where $\mu_A(x) : X \to [0,1]$ & $\nu_A(x) : X \to [0,1]$ are membership degree and non-membership degree, respectively, with the condition: $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ $\pi_A(x)$ determined by the following expression:

$$\pi_A(x) = 1 - \mu_A(x) + \nu_A(x)$$

$\pi_A(x)$ is called the hesitancy degree of the element to the $x \in X$ to the set A, and $\pi_A(x) \in [0,1], \forall x \in X$"

2.3. *Neutrosophic sets* [9]

"Let X be the universal set and $x \in X$.A NS U in X is characterized by a truth membership function ϕ_U , an indeterminacy membership function ν_U and a falsity membership function χ_U where ϕ_U , ν_U and χ_U are real standard elements of [0,1]. It can be written as

$A = \{\langle x, (\phi_U(x), \nu_U(x), \chi_U(x))\rangle : x \in X, \phi_U, \nu_U, \chi_U \in (0,1)$ There is no restriction on the sum of $\phi_U(x)$, $\nu_U(x)$ and $\chi_U(x)$

and so $$0 \leqslant \phi_U(x) + \nu_U(x) + \chi_U(x) \leqslant 3."$$

2.4. *Single - valued neutrosophic sets [11]*

Let X be a space of points (objects) with generic elements in ξ denoted by x . A single valued neutrosophic set A (SVNS) is characterized by truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$. For each point x in $\xi, T_A(x), I_A(x), F_A(x) \in [0,1]$. A SVNS A can be written as

$$A = \{\langle x, (T_A(x), I_A(x), F_A(x))\rangle, x \in \xi\}$$

3. **Operations on single - valued neutrosophic number**

3.1. *Sum of single - valued neutrosophic number*

Let $\tilde{A}_1 = (T_1, I_1, F_1)$ and $\tilde{A}_2 = (T_2, I_2, F_2)$ be two single -valued neutrosophic number then, the sum of SVNS are defined as below;

$$\tilde{A}_1 \oplus \tilde{A}_2 = < T_1 + T_2 - T_1T_2, I_1I_2, F_1F_2, >$$

3.2. *Product of single - valued neutrosophic number*

Let $\tilde{A}_1 = (T_1, I_1, F_1)$ and $\tilde{A}_2 = (T_2, I_2, F_2)$ be two single -valued neutrosophic number then, the product of SVNS are defined as below;

$$\tilde{A}_1 \otimes \tilde{A}_2 = < T_1T_2, I_1 + I_2 - I_1I_2, F_1 + F_2 - F_1F_2 >$$

3.3. *Complement of single - valued neutrosophic fuzzy number*

If $\tilde{A} = \{T(x), I(x), F(x)\}$ is a single - valued neutrosophic number then complement of A is denoted by A^c and is defined by

$$\begin{aligned} T_{A^C}(x) &= F_A(x) \\ I_{A^C}(x) &= 1 - I_A(x) \\ F_{A^C}(x) &= T_A(x) \end{aligned}$$

3.4. *Score, Accuracy and Certainty Functions of Single-Valued Neutrosophic Number*

Let $\tilde{A}_1 = (T_1, I_1, F_1)$ be a single-valued neutrosophic number (SVNS). Then, the score function, accuracy function, and certainty function are defined as follows:

Score function:

$$\tilde{S}(A_1) = \frac{2 + T_1 - I_1 - F_1}{3}$$

Accuracy function:

$$\tilde{a}(A_1) = T_1 - F_1$$

Certainty function:

$$c(A_1) = T_1$$

The score function provides an overall assessment of the neutrosophic number by incorporating truth, indeterminacy, and falsity memberships. The accuracy function measures the dominance of truth over falsity, while the certainty function represents the degree of confidence based solely on truth-membership.

According to [10] Smarandache (2020), the combined use of score, accuracy, and certainty functions establishes a total order on the set of neutrosophic triplets. The ranking of two neutrosophic numbers A_1 and A_2 is performed using the following hierarchical criteria:

(1) Compare score values $\tilde{S}(A_1)$ and $\tilde{S}(A_2)$.
(2) If score values are equal, compare accuracy values $\tilde{a}(A_1)$ and $\tilde{a}(A_2)$.
(3) If both score and accuracy values are equal, compare certainty values $c(A_1)$ and $c(A_2)$.

This approach guarantees a complete ranking (total order) among neutrosophic numbers and eliminates ambiguity in decision-making processes.

4. Fuzzy system reliability evaluation using single-valued neutrosophic fuzzy set

In this section, we present a set of propositions based on a new approach for analyzing the fuzzy reliability of complex systems using the single-valued neutrosophic fuzzy set (SVNS) theory. In this framework, the reliability of each system component is represented by a single-valued neutrosophic number to effectively handle vagueness, imprecision, and incomplete information. The proposed method provides a generalized structure for calculating the overall system reliability for both series and parallel configurations.

Proposition A: If the reliability of each component of a series system is represented as a single-valued neutrosophic number, then the fuzzy reliability of the entire series system, denoted by R_s, is expressed as follows:

$$
\begin{aligned}
R_s &= \bigotimes_{i=1}^{n} R_i = \bigotimes_{i=1}^{n} S_i, \\
R_s &= S_1 \otimes S_2 \otimes S_3 \otimes \cdots \otimes S_n, \\
\text{where each component } S_i &= (T_i, I_i, F_i). \\
\text{Hence,} \quad R_s &= \Bigg(\prod_{i=1}^{n} T_i,\ \sum_{i=1}^{n} I_i - \sum_{i<j}^{n} I_i I_j - \sum_{i<j<k}^{n} I_i I_j I_k + \cdots + (-1)^n \prod_{i=1}^{n} I_i, \\
&\quad \sum_{i=1}^{n} F_i - \sum_{i<j}^{n} F_i F_j - \sum_{i<j<k}^{n} F_i F_j F_k + \cdots + (-1)^n \prod_{i=1}^{n} F_i \Bigg).
\end{aligned}
$$

Explanation: In a series system, the overall system functions successfully only if all individual components operate successfully. Consequently, the truth-membership function (T) of the system reliability is obtained as the product of the truth-membership degrees of all n components, which reflects the joint success probability of the system.

The indeterminacy-membership (I) and falsity-membership (F) functions are computed using the principle of inclusion–exclusion to account for overlapping uncertainties and failures among components. The alternating summation and subtraction terms in I and F capture higher-order dependencies and interactions between uncertain events, allowing the model to represent complex interrelationships among component reliabilities.

This formulation provides a more flexible and realistic expression of system reliability under uncertainty, as it can accommodate incomplete, inconsistent, and vague information that often arises in real-world engineering systems. Therefore, the neutrosophic representation of reliability is more comprehensive than conventional probabilistic or fuzzy reliability approaches.

Proof. : Here we take n components/units which are connected in series Fig.1 If ($R_i = S_i$) be

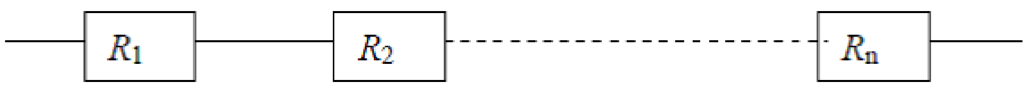

FIGURE 1. Fault tree representation of a Series System

the reliability of the i^{th} component as a form of SVNS (where $i = 1, 2, 3, ..., n,$), then the fuzzy reliability R_s of this system can be calculated as

$$
\begin{aligned}
R_s &= \bigotimes_{i=1}^{n} R_i = \bigotimes_{i=1}^{n} S_i, \\
R_s &= S_1 \otimes S_2 \otimes S_3 \otimes \cdots \otimes S_n, \\
\text{where} \quad S_i &= (T_1, I_1, F_1) \otimes (T_2, I_2, F_2) \otimes \cdots \otimes (T_n, I_n, F_n), \\
&= \Bigg(\prod_{i=1}^{n} T_i, \ \sum_{i=1}^{n} I_i - \sum_{i<j}^{n} I_i I_j - \sum_{i<j<k}^{n} I_i I_j I_k + \cdots + (-1)^n \prod_{i=1}^{n} I_i, \\
&\quad \sum_{i=1}^{n} F_i - \sum_{i<j}^{n} F_i F_j - \sum_{i<j<k}^{n} F_i F_j F_k + \cdots + (-1)^n \prod_{i=1}^{n} F_i \Bigg).
\end{aligned}
$$

□

Proposition B: If the reliability of each component of a parallel system is represented as a single-valued neutrosophic number for handling vagueness and incompleteness in the available information, then the fuzzy reliability of the parallel system, denoted by R_p, is given as follows:

$$R_p = \left(\sum_{i=1}^{n} F_i - \sum_{i<j}^{n} F_iF_j - \sum_{i<j<k}^{n} F_iF_jF_k + \cdots + (-1)^n \prod_{i=1}^{n} F_i, \right.$$
$$\left. \sum_{i=1}^{n} I_i - \sum_{i<j}^{n} I_iI_j - \sum_{i<j<k}^{n} I_iI_jI_k + \cdots + (-1)^n \prod_{i=1}^{n} I_i, \prod_{i=1}^{n} T_i \right).$$

Proof. Let n components be connected in parallel as shown in Figure 2. If $R_i = S_i$ represents the reliability of the i^{th} component in the form of a single-valued neutrosophic number, where $S_i = (T_i, I_i, F_i)$ and $i = 1, 2, 3, \ldots, n$, then the overall fuzzy reliability of the system can be determined using the neutrosophic complement and aggregation operations as:

$$R_p = \left(\bigotimes_{i=1}^{n} R_i^c \right)^c,$$

$$(R_p)^c = \bigotimes_{i=1}^{n} R_i^c,$$

$$(R_p)^c = \bigotimes_{i=1}^{n} S_i^c,$$

$$(R_p)^c = S_1^c \otimes S_2^c \otimes S_3^c \otimes \cdots \otimes S_n^c,$$
$$= \left(\sum_{i=1}^{n} F_i - \sum_{i<j}^{n} F_iF_j - \sum_{i<j<k}^{n} F_iF_jF_k + \cdots + (-1)^n \prod_{i=1}^{n} F_i, \right.$$
$$\left. \sum_{i=1}^{n} I_i - \sum_{i<j}^{n} I_iI_j - \sum_{i<j<k}^{n} I_iI_jI_k + \cdots + (-1)^n \prod_{i=1}^{n} I_i, \prod_{i=1}^{n} T_i \right).$$

□

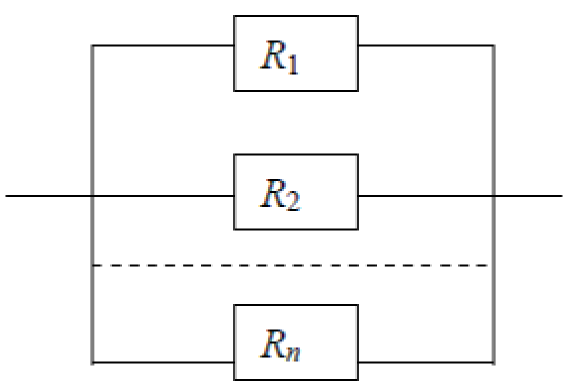

FIGURE 2. Fault tree representation of a Parallel System

Explanation: In a parallel system, the overall system functions successfully as long as at least one of its components operates. This property is reflected in the reliability formulation through the complement operation, where the system failure occurs only when all components fail simultaneously.

The truth-membership function (T) of the system reliability is therefore computed as the product of the truth-membership degrees of all individual components, representing the combined probability of their successful operation. Conversely, the falsity (F) and indeterminacy (I) memberships are expressed using inclusion–exclusion principles to capture overlapping uncertainties and dependencies among components.

This formulation ensures that the neutrosophic-based reliability expression for parallel systems comprehensively models not only uncertainty but also the degrees of hesitation and contradiction, leading to a more realistic and robust evaluation compared to traditional fuzzy or probabilistic reliability models.

5. **Fuzzy Success-Fault Tree Analysis of Robotic System Reliability Using SVNS**

5.1. *System Description*

In this study, we present a comprehensive reliability analysis of a robotic system by employing the framework of Single-Valued Neutrosophic Sets (SVNS) to effectively capture uncertainties, vagueness, and incomplete information associated with engineering components. The proposed system consists of two robotic units interconnected through a conveyor unit (CU), which is commonly utilized in industrial automation and material handling operations. Each robotic unit is designed as a multi-component subsystem comprising several joints, where each joint integrates a motor (M_i) responsible for actuation and a sensor (S_i) responsible for detecting position, motion, and operational status. The conveyor unit serves as the intermediate link between the two robots, enabling synchronized material transfer and mechanical coordination. It primarily consists of two vital components a roller (R_l), which ensures continuous motion of the conveyor belt, and a bearing (B_r), which facilitates smooth rotation and reduces frictional losses. Together, these components form an interdependent structure whose performance directly influences the overall reliability of the robotic system. The Fault Tree of the Robotic System (FTRS) is developed to systematically represent these interconnections and failure dependencies among the robotic subsystems and the conveyor unit. The system is logically divided into two sequential series subsystems, denoted as S_1 and S_2, corresponding to the two primary sensors that regulate the operations of both robotic units and the conveyor mechanism. Within the fault tree framework, the various elements are connected through combinations of series and parallel configurations to reflect realistic operational dependencies. This representation allows for accurate computation of the system's overall reliability while addressing the inherent indeterminacy and imprecision in component behavior through the use of neutrosophic fuzzy modeling.

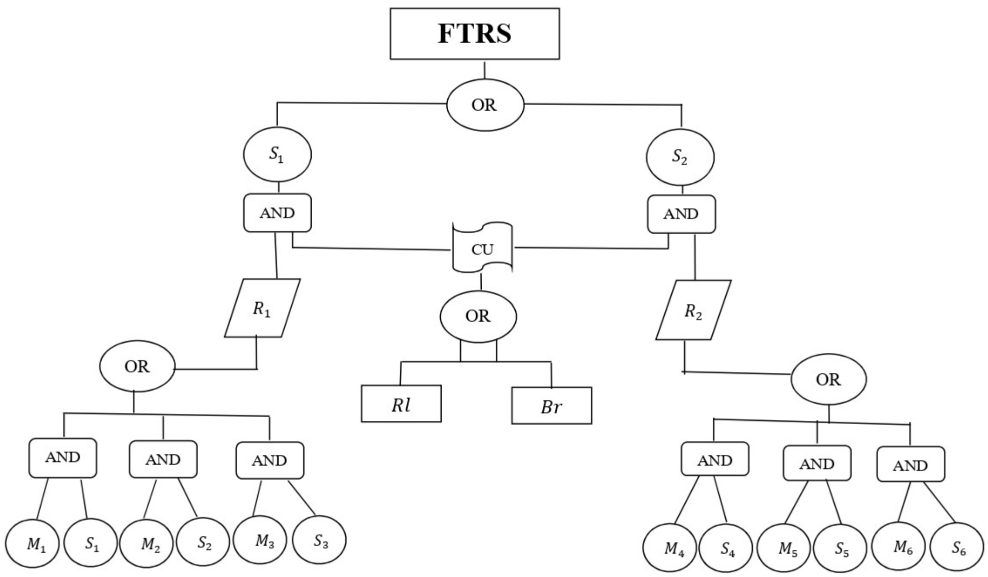

FIGURE 3. Fault Tree of the Robotic System (FTRS)

In order to capture the uncertainty and imprecision associated with component reliability in the robotic system, each element of the system such as motors, sensors, roller, and bearing is represented using the framework of Single-Valued Neutrosophic Sets (SVNS). The neutrosophic representation of a component is defined by a triplet $\{T, I, F\}$, where T denotes the degree of truth-membership or reliability (the extent to which the component performs its intended function successfully), I represents the degree of indeterminacy or hesitation due to incomplete or conflicting information, and F signifies the degree of falsity or unreliability (the likelihood of failure or malfunction). This representation provides a flexible mathematical structure to model real-world uncertainties that cannot be expressed adequately by classical probability or fuzzy logic alone.

For the robotic system under consideration, the motors are denoted as M_1 to M_6, the sensors as S_1 to S_6, while the conveyor unit comprises a roller (R_l) and a bearing (B_r). The reliability values of each component are assigned in the form of SVNS triplets as follows:

$$M_1 = \{0.3, 0.8, 0.8\}, \quad M_2 = \{0.1, 0.2, 0.5\}, \quad M_3 = \{0.8, 0.6, 0.1\},$$
$$M_4 = \{0.12, 0.21, 0.31\}, \quad M_5 = \{0.31, 0.40, 0.91\}, \quad M_6 = \{0.88, 0.36, 0.11\},$$
$$S_1 = \{0.2, 0.7, 0.7\}, \quad S_2 = \{0, 0.1, 0.4\}, \quad S_3 = \{0.7, 0.5, 0\},$$
$$S_4 = \{0.02, 0.11, 0.21\}, \quad S_5 = \{0.21, 0.30, 0.81\}, \quad S_6 = \{0.78, 0.26, 0.01\},$$
$$R_l = \{0.30, 0.81, 0.99\}, \quad B_r = \{0.6, 0.9, 1\}.$$

Here, for example, the motor M_1 with $\{T, I, F\} = \{0.3, 0.8, 0.8\}$ indicates that the component has a relatively low degree of reliability ($T = 0.3$), but a high level of uncertainty ($I = 0.8$) and failure possibility ($F = 0.8$), suggesting that it is a weak or degraded component in the system. Conversely, the motor M_3 with $\{0.8, 0.6, 0.1\}$ shows high reliability and low falsity, implying that it performs well under uncertain operating conditions. Similarly, the bearing $B_r = \{0.6, 0.9, 1\}$ demonstrates moderate reliability but a very high indeterminacy and maximum falsity, reflecting its critical influence on system failure if not properly maintained.

The sensors (S_1–S_6) exhibit varying levels of performance and uncertainty, highlighting the diversity of sensor quality and operational precision within the robotic system. For instance, $S_3 = \{0.7, 0.5, 0\}$ has a high truth-membership and no falsity, implying strong reliability, whereas $S_2 = \{0, 0.1, 0.4\}$ represents a highly unreliable component. Similarly, the roller component $R_l = \{0.30, 0.81, 0.99\}$ indicates that while its reliability is low, the associated indeterminacy and failure likelihood are significantly high, demonstrating its vulnerability to operational stress and wear.

By modeling all these components through SVNS, the system can be evaluated in a unified framework that considers not only binary success or failure states but also the intermediate degrees of uncertainty. This enables a more accurate and realistic estimation of overall system reliability and performance, particularly in cases where component reliability data are incomplete, expert-based, or derived from uncertain environments.

5.2. *Series and Parallel Reliability Calculations*

Consider motors M_1, M_2, M_3 and sensors S_1, S_2, S_3 connected at points A, B, and C in a series configuration. The series reliability of these three points is computed as:

$$(MS)_R = \{(A^C \otimes B^C) \otimes C\}^C = \{0.0658, 0.78944, 0.5864\}.$$

Since the robots are connected in parallel, the combined reliability is:

$$(MSR_1)_R = \{0.5864, 0.21056, 0.0658\}.$$

Similarly, when the roller and bearing are connected in parallel with the conveyor unit, the reliability becomes:

$$\{R_1 \otimes CU\} = \{0.422208, 0.78606176, 0.990658\},$$
$$\{R_2 \otimes CU\} = \{0.559568236, 0.753565373, 0.995316272\}.$$

The overall robotic system reliability is obtained by combining S_1 and S_2:

$$\{(S_1)^C \otimes (S_2)^C\} = \{0.986018027, 0.407651077, 0.74552205\},$$
$$FTRS = \{0.986018027, 0.407851077, 0.74552205\}.$$

5.3. *Score, Accuracy and Certainty Evaluation*

To quantitatively evaluate the overall reliability of the robotic system, the score, accuracy, and certainty functions are applied to the obtained neutrosophic reliability value.

The final reliability of the system is given by:

$$\text{FTRS} = (0.986018027,\ 0.407851077,\ 0.74552205)$$

Using the definitions provided in Section 3.4, we obtain:

Score function:

$$\tilde{S}(A_1) = \frac{2 + T_1 - I_1 - F_1}{3} = 0.6109483$$

Accuracy function:

$$\tilde{a}(A_1) = T_1 - F_1 = 0.240495977$$

Certainty function:

$$c(A_1) = T_1 = 0.986018027$$

The score value reflects the overall system performance considering uncertainty and failure, while the accuracy function indicates the dominance of reliability over unreliability. The certainty function highlights the degree of confidence associated with the system's reliability based on truth-membership.

Together, these three measures provide a comprehensive and consistent evaluation framework. In particular, the inclusion of the certainty function ensures completeness in ranking and aligns the proposed methodology with the total order principle of neutrosophic triplets.

5.4. *Discussion*

The proposed FTRS framework allows for comprehensive modeling of robotic systems, accounting for series and parallel interactions among critical components. Using SVNS enables handling incomplete and ambiguous information, making it highly suitable for industrial robotic applications where component reliability may be uncertain. The system analysis reveals that the conveyor-based robotic system achieves high reliability, primarily due to redundancy in sensor and motor configurations.

6. **Conclusion**

In this paper, a neutrosophic-based framework has been proposed for the fuzzy reliability analysis of complex engineering systems using Single-Valued Neutrosophic Sets (SVNS). The fundamental idea is to represent each system component as a neutrosophic triplet, thereby capturing not only its reliability (truth-membership) but also the associated indeterminacy and falsity. This representation enables a more realistic and comprehensive modeling of uncertainty in practical engineering environments. Using the developed propositions and operational rules on SVNS, the reliability of a robotic system consisting of motors, sensors, rollers, and bearings has been analyzed through a fuzzy success fault tree model. The system structure, involving both series and parallel configurations, has been systematically evaluated to understand the impact of individual components and their interdependencies on overall system performance.

To ensure a consistent and comprehensive evaluation of neutrosophic reliability measures, three decision-making functions namely score, accuracy, and certainty have been employed. While the score function provides an overall assessment and the accuracy function measures the dominance of reliability over unreliability, the certainty function captures the degree of confidence based on truth-membership. The combined use of these three functions establishes a total order on neutrosophic triplets, thereby eliminating ambiguity and ensuring a complete and reliable comparison framework. The results demonstrate that the proposed neutrosophic approach offers significant advantages over classical probabilistic and conventional fuzzy models, particularly in handling imprecise, incomplete, and inconsistent information. The methodology is well-suited for applications in robotic systems, automated manufacturing, and other complex engineering domains where uncertainty plays a critical role.

Moreover, the proposed SVNS-based framework is sufficiently flexible to be extended to non-series-parallel (NSP) systems, electronic circuits, and other multi-component systems. This highlights its potential as a powerful decision-support tool for engineers and researchers dealing with uncertainty-driven reliability problems. In conclusion, the integration of score, accuracy, and certainty functions within the neutrosophic framework not only enhances the robustness of reliability analysis but also ensures completeness in decision-making. The proposed approach provides a structured and adaptable methodology for modeling uncertainty, thereby opening new avenues for future research in fuzzy reliability analysis, optimization, and intelligent system design.

Funding: This research was funded by Kumaun University, Nainital, under the KUFIR-III project.

Conflicts of Interest: The authors declare no conflict of interest.

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Received: Nov 6, 2025. Accepted: May 20, 2026