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Refined Neutrosophic Set approach for Musculoskeletal disorders

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Abstract. Musculoskeletal disorders are often characterized by persistent joint pain, stiffness, swelling, and reduced mobility, which can severely impact daily functioning and quality of life. These conditions often present overlapping symptoms, making accurate diagnosis a significant challenge in clinical settings. Traditional diagnostic approaches may struggle with the inherent uncertainty, vagueness, and imprecision found in medical data. This paper proposes a novel approach for classifying four musculoskeletal disorders using the Neutrosophic Refined Set framework, with a particular focus on correlation and distance-based measures. Neutrosophic Refined Set, an advanced extension of neutrosophic logic, provides a robust mathematical model for handling indeterminate and inconsistent information, making it particularly well-suited for healthcare applications.

The proposed work is illustrated with four musculoskeletal disorders - Rheumatoid Arthritis, Osteoarthritis, Lupus, Bursitis and the eight associated Rheumatic symptoms. Correlation analysis is employed to determine the most prevalent symptom group associated with each disorder. Also, the distance measures - Hamming distance, Normalized Hamming distance, Euclidean distance, and Normalized Euclidean distance are used to compute the proximity of four patient cases to each disorder. Python implementation of the proposed method is used to streamline the computational process, offering a faster, more accurate, and less error-prone alternative to manual calculations. Also, highly informative visualizations are employed to illustrate the general trends in symptom intensity and distribution across the four musculoskeletal disorders. Overall, this approach demonstrates the potential of Neutrosophic Refined Sets in enhancing diagnostic accuracy, managing uncertainty, and supports clinical decision-making.

Keywords: Musculoskeletal disorders, Rheumatoid Arthritis, Osteoarthritis, Lupus, Bursitis, Neutrosophic set, Neutrosophic Refined set, Dimension, Hamming distance, Normalised hamming distance, Euclidean distance, Normalised euclidean distance, Correlation Measure

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1. Introduction

Neutrosophic logic and sets, introduced by Florentin Smarandache in 1995 [12, 13], offer a powerful framework for handling uncertainty and imprecision in various real-world applications, including decision making, medical diagnosis and image processing. Unlike the traditional binary logic (True or False) or fuzzy logic that allows degree of truth, neutrosophic sets introduce the concept of indeterminacy, thus incorporating three independent components: truth (T), indeterminacy (I), and fallacy (F). This allows for a more nuanced representation of information making it particularly useful in scenarios where ambiguity is prevalent.

In recent years, the application of soft computing techniques, particularly those based on neutrosophic sets and fuzzy logic, has seen significant growth in the field of medical diagnosis. Several Python-based frameworks and tools have emerged to support modeling and reasoning under uncertainty [7–9]. These developments reflect a shift toward practical, open-source implementations that bridge theoretical methods with real-world diagnostic applications. Recent studies have also extended neutrosophic similarity and correlation measures to domains such as COVID-19 detection and pattern recognition [18, 20], reinforcing the relevance of soft computing approaches in contemporary medical decision support systems.

Neutrosophic Refined Sets, which was introduced by Irfan Deli, Said Broumi, Florentin Smarandache (2015) [1], is a generalisation of fuzzy multisets and intuitionstic fuzzy multisets. Similar to Neutrosophic sets they have the three components - truth (T), indeterminacy (I), and fallacy (F) but allow multiple values of these components, referred to as the dimension (P) of the set. This multi-valued nature enhances the ability of Neutrosophic Refined sets to capture complex real-world scenarios with varying degrees of uncertainty. The work [1] includes the definitions for the operations such as complement, union, intersection, convex, strongly convex, containment, equality and the four distance measures - hamming distance, normalised hamming distance, euclidean distance and normalised euclidean distance. Paper [14] gives the definition for the correlation measure, which can be used to find the similarity or dissimilarity between two Neutrosophic Refined sets.

For the purpose of illustrating the methodology proposed four musculoskeletal disorders - Rheumatoid Arthritis, Osteoarthritis, Lupus and Bursitis are considered. Rheumatic symptoms are generally associated with Rheumatic diseases, that are characterized by conditions affecting the muscles, bones, joints, tendons, ligaments, cartilage often causing pain, swelling, and stiffness and are sometimes referred to as musculoskeletal disorders. Individuals affected by any of these four disorders will experience one or more of these eight rheumatic symptoms

- joint pain, stiffness in the joints especially during morning, fatigue, swelling in the joints, difficulty while moving the joints, persistence of pain in the joints while at rest, round scaly rashes in the skin and pain in the smaller joints.

The remainder of this paper is organized as follows. Section 2 introduces the fundamental definitions related to Neutrosophic Refined Sets, which form the basis for subsequent discussions, and provides a brief overview of the four musculoskeletal disorders under consideration. Section 3 outlines the proposed work, with the Python implementation of correlation and distance measures for Neutrosophic Refined Sets [5–9] and presents three illustrative examples [1–4, 14–20]: the first demonstrates the classification of disorders based on symptom groups; the second focuses on patient diagnosis by computing the distance between a patient's symptom profile and each of the four disorders using the distance measures; and the third offers informative visualizations that reflect the general symptom trends associated with each disorder. Finally, Section 4 concludes the study.

2. **Preliminaries**

This section delves into the foundational concepts of Neutrosophic Refined Sets (NRS) which are used in the further sections of this paper. Also, a detailed overview of the four musculoskeletal disorders that are the focus of this study is provided.

2.1. *Definitions*

Definition 1. *[1] Let E be the universe. Then a Neutrosophic Refined set A defined on E with dimension P is given by*

$$A = \{(T^1_{\mathtt{A}}(x), T^2_{\mathtt{A}}(x), ..., T^P_{\mathtt{A}}(x)), (I^1_{\mathtt{A}}(x), I^2_{\mathtt{A}}(x), ..., I^P_{\mathtt{A}}(x)), (F^1_{\mathtt{A}}(x), F^2_{\mathtt{A}}(x), ..., F^P_{\mathtt{A}}(x)) : x \in X\} \tag{1}$$

Another Neutrosophic Refined set B defined on E with the same dimension P will be of the form

$$B = \{(T^1_{\mathtt{B}}(x), T^2_{\mathtt{B}}(x), ..., T^P_{\mathtt{B}}(x)), (I^1_{\mathtt{B}}(x), I^2_{\mathtt{B}}(x), ..., I^P_{\mathtt{B}}(x)), (F^1_{\mathtt{B}}(x), F^2_{\mathtt{B}}(x), ..., F^P_{\mathtt{B}}(x)) : x \in X\} \tag{2}$$

Definition 2. *[1] Hamming distance between A and B is denoted as $d_{\mathtt{HD}}(A, B)$ and is given by*

$$d_{\mathtt{HD}}(A, B) = \sum_{j=1}^{P} \sum_{i=1}^{n} (|T^j_{\mathtt{A}}(x_{\mathtt{i}}) - T^j_{\mathtt{B}}(x_{\mathtt{i}})| + |I^j_{\mathtt{A}}(x_{\mathtt{i}}) - I^j_{\mathtt{B}}(x_{\mathtt{i}})| + |F^j_{\mathtt{A}}(x_{\mathtt{i}}) - F^j_{\mathtt{B}}(x_{\mathtt{i}})|) \tag{3}$$

Definition 3. *[1] Normalised Hamming distance between A and B is denoted as $d_{\mathtt{NHD}}(A,B)$ and is given by*

$$d_{\mathtt{NHD}}(A,B) = \frac{1}{3nP}\sum_{j=1}^{P}\sum_{i=1}^{n}(|T_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - T_{\mathtt{B}}^{j}(x_{\mathtt{i}})| + |I_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - I_{\mathtt{B}}^{j}(x_{\mathtt{i}})| + |F_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - F_{\mathtt{B}}^{j}(x_{\mathtt{i}})|) \quad (4)$$

Definition 4. *[1] Euclidean distance between A and B is denoted as $d_{\mathtt{ED}}(A,B)$ and is given by*

$$d_{\mathtt{ED}}(A,B) = \sum_{j=1}^{P}\sum_{i=1}^{n}\sqrt{(T_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - T_{\mathtt{B}}^{j}(x_{\mathtt{i}}))^2 + (I_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - I_{\mathtt{B}}^{j}(x_{\mathtt{i}}))^2 + (F_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - F_{\mathtt{B}}^{j}(x_{\mathtt{i}}))^2} \quad (5)$$

Definition 5. *[1] Normalised Euclidean distance A and B is denoted as $d_{\mathtt{NED}}(A,B)$ and is given by*

$$d_{\mathtt{NED}}(A,B) = \frac{1}{3nP}\sum_{j=1}^{P}\sum_{i=1}^{n}\sqrt{(T_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - T_{\mathtt{B}}^{j}(x_{\mathtt{i}}))^2 + (I_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - I_{\mathtt{B}}^{j}(x_{\mathtt{i}}))^2 + (F_{\mathtt{A}}^{j}(x_{\mathtt{i}}) - F_{\mathtt{B}}^{j}(x_{\mathtt{i}}))^2} \quad (6)$$

Definition 6. *[14] Correlation measure between A and B is denoted as $\rho_{\mathtt{NRS}}(A,B)$ and is given by*

$$C_{\mathtt{NRS}}(A,B) = \frac{1}{P}\sum_{j=1}^{P}\sum_{i=1}^{n}(T_{\mathtt{A}}^{j}(x_{\mathtt{i}}) * T_{\mathtt{B}}^{j}(x_{\mathtt{i}}) + I_{\mathtt{A}}^{j}(x_{\mathtt{i}}) * I_{\mathtt{B}}^{j}(x_{\mathtt{i}}) + F_{\mathtt{A}}^{j}(x_{\mathtt{i}}) * F_{\mathtt{B}}^{j}(x_{\mathtt{i}}))$$

$$C_{\mathtt{NRS}}(A,A) = \frac{1}{P}\sum_{j=1}^{P}\sum_{i=1}^{n}(T_{\mathtt{A}}^{j}(x_{\mathtt{i}}) * T_{\mathtt{A}}^{j}(x_{\mathtt{i}}) + I_{\mathtt{A}}^{j}(x_{\mathtt{i}}) * I_{\mathtt{A}}^{j}(x_{\mathtt{i}}) + F_{\mathtt{A}}^{j}(x_{\mathtt{i}}) * F_{\mathtt{A}}^{j}(x_{\mathtt{i}}))$$

$$C_{\mathtt{NRS}}(B,B) = \frac{1}{P}\sum_{j=1}^{P}\sum_{i=1}^{n}(T_{\mathtt{B}}^{j}(x_{\mathtt{i}}) * T_{\mathtt{B}}^{j}(x_{\mathtt{i}}) + I_{\mathtt{B}}^{j}(x_{\mathtt{i}}) * I_{\mathtt{B}}^{j}(x_{\mathtt{i}}) + F_{\mathtt{B}}^{j}(x_{\mathtt{i}}) * F_{\mathtt{B}}^{j}(x_{\mathtt{i}}))$$

$$\rho_{\mathtt{NRS}}(A,B) = \frac{C_{\mathtt{NRS}}(A,B)}{\sqrt{C_{\mathtt{NRS}}(A,A) * C_{\mathtt{NRS}}(B,B)}} \quad (7)$$

To demonstrate the application of distance and correlation measures in a medical context, consider two patients A and B having fever. The Neutrosophic Refined Sets formed with the T, I and F values recorded three times a day for both the patients are presented below.

$$\text{Patient}_{\mathtt{A}} = \{(0.85, 1.0, 0.85),\ (0.15, 0.25, 0.1),\ (0.2, 0.15, 0.05)\}$$

$$\text{Patient}_{\mathtt{B}} = \{(0.85, 0.95, 0.8),\ (0.15, 0.2, 0.05),\ (0.25, 0.1, 0.1)\}$$

From the values of the distance and correlation measures presented in Table 1, it can be observed that the distance measures indicate a low to moderate difference between the patients, while the correlation measure highlights a strong similarity. Together, these results emphasize that patients A and B exhibit a similar pattern or nature of fever.

Table 1. Distance and Correlation measure outcome with Interpretations

Measure	**Value**	**Meaning**
Hamming Distance (HD)	0.35	Moderate absolute difference
Normalized Hamming Distance (NHD)	0.039	Very small distance
Euclidean Distance (ED)	0.132	Low difference
Normalized Euclidean Distance (NED)	0.015	Negligible difference
Correlation Measure (ρ_{NRS})	0.997	Extremely strong similarity in trend

2.2. *Musculoskeletal disorders*

Musculoskeletal disorders refer to conditions that cause pain or injury to the components of the musculoskeletal system, such as muscles, tendons, ligaments, joints, nerves, and the supporting structures of the back, neck, and limbs. These disorders may result from sudden physical effort, such as lifting or carrying heavy objects, or they may develop over time due to repetitive movements, prolonged exposure to mechanical stress, vibration, or sustained awkward postures.

The term "Arthritis" literally means joint inflammation. Arthritis is the swelling and tenderness of one or more joints. The most common types of arthritis are Osteoarthritis and Rheumatoid Arthritis. [21].

Rheumatoid Arthritis (RA) is a form of arthritis and a chronic autoimmune disease that attacks the body's own tissues, causing inflammation in joints, skin, eyes, heart, and blood vessels. This inflammation can lead to pain, swelling, stiffness, and even joint damage as uncontrolled inflammation damages cartilage which acts as a shock absorber in the joints and thus can deform the joints and eventually causes the bone to erode. [21] One of the most common symptoms of RA is swollen joints, often accompanied by stiffness that is particularly severe in the morning or after periods of inactivity. Fatigue is another common complaint among those with RA. Women are more likely than men to develop this condition, and it typically begins in middle age.

There are four clinically recognized stages of Rheumatoid Arthritis (RA), described as follows:

- Stage 1 (Early Stage): Mild joint pain and stiffness begin to appear, accompanied by inflammation around the joints. Structural damage is minimal at this point.
- Stage 2 (Moderate Stage): Inflammation progresses and starts affecting the cartilage, resulting in increased stiffness and a noticeable reduction in joint mobility.
- Stage 3 (Severe Stage): The inflammatory response becomes more aggressive, leading to bone erosion. Patients typically experience significant pain, stiffness, restricted movement, and visible joint deformities.

- Stage 4 (Final Stage): Although active inflammation may subside, joint damage continues. This stage is characterized by chronic pain, swelling, severe stiffness, and substantial loss of joint function and mobility. [21]

Osteoarthritis is a most common form of Arthritis and is a degenerative disease with the condition worsening over time. Joint pain and stiffness can be severe especially in hands, hip, knees and spine.

It is more common in older adults and can be one of the two types:

- Primary osteoarthritis that develops in the joints over time that might be caused by normal wear and tear of joints.
- Secondary osteoarthritis might happen when something directly damages the joints like injuries. [21]

Lupus is an autoimmune disorder which can cause inflammation in joints, skin, kidneys, blood cells, brain, heart and lungs. One distinctive symptom could be butterfly - shaped rashes on the face that covers the cheeks and bridge of the nose or elsewhere on the body. Lupus rashes also includes:

- Discoid Lupus, which causes red, scaly patches on the skin
- Subacute Cutaneous Lupus, which causes ring-shaped or oval-shaped rashes on the skin. [21]

Bursitis is a painful condition that causes swelling, usually around the joints. It is more common in the shoulders, elbows, knees and feet. Bursitis causes swelling in brusa - a small, fluid-filled sac, which is found around bones and some other tissues. Bursitis often occurs near joints that perform frequent repetitive motion. [21]

Several factors can increase the risk of developing musculoskeletal disorders which includes age, occupation, injury, genetics and lifestyle factors. Certain activities that can cause wear and tear of the joints and lead to musculoskeletal disorders includes engaging in tasks that involve repetitive motions, lifting heavy weights and maintaining poor posture.

3. **Proposed Work**

3.1. *Correlation-based analysis of symptom patterns across disorders*

Consider the four musculoskeletal disorders - Rheumatoid Arthritis, Osteoarthritis, Lupus, Bursitis and the eight rheumatic symptoms - joint pain, morning joint stiffness, fatigue, swelling in the joints, impaired joint mobility, pain relief during rest, annular or oval scaly rashes in the skin and pain in the smaller joints. The tables 2, 3, 4 and 5 present the T, I and F values of four sets of three patients Patient 1, Patient 2, Patient 3 suffering from each disorder, recorded at four-month intervals over the span of one year. [14]

Table 2. Rheumatoid Arthritis

	Rheumatoid Arthritis Patient 1	Rheumatoid Arthritis Patient 2	Rheumatoid Arthritis Patient 3
Joint pain	(1.0,0.3,0.0) (0.9,0.4,0.1) (0.9,0.1,0.1)	(0.9,0.4,0.0) (1.0,0.2,0.0) (0.9,0.2,0.1)	(0.9,0.3,0.0) (1.0,0.5,0.1) (1.0,0.1,0.1)
Morning joint stiffness	(0.9,0.2,0.1) (0.9,0.4,0.0) (1.0,0.3,0.1)	(1.0,0.1,0.0) (0.9,0.3,0.1) (0.9,0.5,0.1)	(0.9,0.4,0.1) (1.0,0.5,0.0) (1.0,0.1,0.1)
Fatigue	(0.1,0.2,0.9) (0.1,0.3,0.8) (0.0,0.2,0.9)	(0.1,0.3,1.0) (0.0,0.5,0.8) (1.0,0.4,0.9)	(0.1,0.2,0.9) (0.0,0.2,0.8) (0.1,0.1,0.8)
Swelling in the joints	(0.9,0.3,0.1) (0.8,0.4,0.3) (0.8,0.3,0.2)	(0.8,0.4,0.2) (0.9,0.5,0.2) (0.8,0.1,0.3)	(0.9,0.4,0.1) (0.9,0.1,0.2) (0.8,0.1,0.1)
Impaired joint mobility	(0.8,0.3,0.1) (0.7,0.2,0.3) (0.6,0.3,0.2)	(0.9,0.4,0.2) (0.8,0.3,0.1) (0.8,0.2,0.1)	(0.8,0.4,0.1) (0.7,0.2,0.2) (0.8,0.2,0.1)
Pain relief during rest	(0.3,0.1,0.7) (0.2,0.3,0.8) (0.4,0.2,0.6)	(0.4,0.2,0.8) (0.3,0.3,0.8) (0.2,0.1,0.7)	(0.3,0.1,0.8) (0.2,0.2,0.8) (0.3,0.2,0.7)
Annular or oval scaly rashes	(0.0,0.4,0.9) (0.0,0.1,1.0) (0.0,0.2,0.9)	(0.0,0.3,0.9) (0.0,0.2,1.0) (0.0,0.4,1.0)	(0.0,0.4,0.9) (0.0,0.1,1.0) (0.0,0.1,0.9)
Pain in the smaller joints	(0.8,0.2,0.0) (0.9,0.4,0.1) (0.9,0.3,0.0)	(0.7,0.5,0.1) (0.8,0.5,0.2) (0.9,0.1,0.2)	(0.9,0.6,0.1) (0.9,0.4,0.0) (0.6,0.3,0.2)

Table 3. Oseteoarthritis

	Osteo-arthritis Patient 1	Osteo-arthritis Patient 2	Osteo-arthritis Patient 3
Joint pain	(0.9,0.3,0.1) (1.0,0.4,0.0) (0.9,0.1,0.1)	(0.9,0.4,0.0) (1.0,0.2,0.1) (1.0,0.2,0.0)	(0.9,0.3,0.0) (0.9,0.5,0.1) (1.0,0.1,0.1)
Morning joint stiffness	(0.3,0.2,0.9) (0.2,0.4,0.8) (0.1,0.3,0.8)	(0.3,0.1,0.8) (0.3,0.3,0.8) (0.2,0.5,0.7)	(0.2,0.4,0.9) (0.3,0.5,0.8) (0.1,0.1,0.8)
Fatigue	(0.0,0.5,0.9) (0.0,0.6,1.0) (0.1,0.3,0.9)	(0.0,0.3,0.9) (0.1,0.2,1.0) (0.1,0.2,1.0)	(0.0,0.4,1.0) (0.0,0.1,0.9) (0.1,0.1,0.9)
Swelling in the joints	(0.5,0.3,0.4) (0.7,0.4,0.3) (0.6,0.3,0.2)	(0.5,0.4,0.4) (0.6,0.5,0.4) (0.6,0.1,0.3)	(0.5,0.4,0.5) (0.6,0.1,0.3) (0.5,0.1,0.4)
Impaired joint mobility	(0.8,0.3,0.1) (0.9,0.2,0.0) (0.9,0.3,0.0)	(0.9,0.4,0.1) (1.0,0.3,0.1) (0.9,0.2,0.0)	(1.0,0.4,0.1) (0.9,0.2,0.0) (0.9,0.2,0.0)
Pain relief during rest	(0.5,0.3,0.3) (0.4,0.4,0.3) (0.3,0.2,0.4)	(0.5,0.2,0.4) (0.6,0.5,0.3) (0.5,0.4,0.4)	(0.6,0.3,0.4) (0.5,0.4,0.3) (0.4,0.3,0.5)
Annular or oval scaly rashes	(0.0,0.4,0.9) (0.0,0.1,1.0) (0.1,0.2,1.0)	(0.1,0.3,0.9) (0.0,0.2,0.8) (0.1,0.4,1.0)	(0.0,0.4,1.0) (0.1,0.1,0.8) (0.1,0.1,0.9)
Pain in the smaller joints	(0.0,0.2,0.8) (0.1,0.4,0.9) (0.0,0.3,0.9)	(0.1,0.5,0.9) (0.1,0.5,1.0) (0.2,0.1,0.9)	(0.1,0.6,0.9) (0.0,0.4,0.9) (0.2,0.3,0.8)

Table 4. Lupus

	Lupus Patient 1	Lupus Patient 2	Lupus Patient 3
Joint pain	(0.5,0.3,0.4) (0.6,0.4,0.3) (0.5,0.1,0.6)	(0.6,0.4,0.5) (0.5,0.2,0.4) (0.5,0.2,0.3)	(0.5,0.3,0.5) (0.6,0.5,0.4) (0.4,0.1,0.3)
Morning joint stiffness	(0.6,0.2,0.4) (0.6,0.4,0.3) (0.5,0.3,0.4)	(0.6,0.1,0.4) (0.5,0.3,0.3) (0.5,0.5,0.5)	(0.6,0.4,0.3) (0.5,0.5,0.3) (0.6,0.1,0.4)
Fatigue	(0.9,0.3,0.1) (1.0,0.2,0.0) (0.9,0.3,0.1)	(0.9,0.3,0.0) (1.0,0.4,0.1) (1.0,0.2,0.1)	(1.0,0.4,0.0) (0.9,0.1,0.0) (0.9,0.1,0.1)
Swelling in the joints	(0.5,0.3,0.4) (0.7,0.4,0.3) (0.6,0.3,0.2)	(0.5,0.4,0.4) (0.6,0.5,0.4) (0.6,0.1,0.3)	(0.5,0.4,0.5) (0.6,0.1,0.3) (0.5,0.1,0.4)
Impaired joint mobility	(0.5,0.3,0.4) (0.5,0.4,0.3) (0.3,0.2,0.4)	(0.6,0.2,0.4) (0.6,0.5,0.3) (0.5,0.4,0.3)	(0.6,0.3,0.4) (0.5,0.4,0.5) (0.5,0.3,0.5)
Pain relief during rest	(0.5,0.3,0.5) (0.4,0.4,0.3) (0.6,0.2,0.4)	(0.5,0.2,0.4) (0.6,0.5,0.3) (0.5,0.4,0.3)	(0.6,0.3,0.4) (0.5,0.4,0.3) (0.6,0.3,0.4)
Annular or oval scaly rashes	(0.9,0.5,0.1) (0.9,0.6,0.1) (1.0,0.3,0.1)	(0.9,0.3,0.0) (0.9,0.3,0.0) (1.0,0.1,0.1)	(1.0,0.2,0.1) (0.9,0.1,0.0) (0.9,0.1,0.1)
Pain in the smaller joints	(0.5,0.3,0.5) (0.5,0.4,0.3) (0.4,0.2,0.4)	(0.6,0.2,0.4) (0.6,0.5,0.5) (0.6,0.4,0.4)	(0.6,0.3,0.4) (0.5,0.4,0.3) (0.6,0.3,0.3)

Table 5. Bursitis

	Bursitis Patient 1	Bursitis Patient 2	Bursitis Patient 3
Joint pain	(1.0,0.3,0.0) (1.0,0.2,0.1) (0.9,0.1,0.0)	(0.9,0.4,0.0) (1.0,0.3,0.1) (0.9,0.2,0.1)	(0.9,0.3,0.0) (1.0,0.4,0.0) (1.0,0.1,0.1)
Morning joint stiffness	(0.3,0.4,0.7) (0.4,0.1,0.8) (0.3,0.2,0.8)	(0.3,0.3,0.7) (0.2,0.2,0.8) (0.4,0.4,0.7)	(0.3,0.4,0.7) (0.4,0.1,0.7) (0.2,0.1,0.8)
Fatigue	(0.3,0.2,0.7) (0.4,0.3,0.8) (0.2,0.2,0.7)	(0.2,0.3,0.7) (0.3,0.5,0.8) (0.3,0.4,0.7)	(0.3,0.2,0.7) (0.2,0.2,0.8) (0.4,0.1,0.8)
Swelling in the joints	(0.8,0.2,0.0) (0.9,0.4,0.1) (0.9,0.3,0.0)	(1.0,0.5,0.1) (0.9,0.5,0.1) (0.8,0.1,0.0)	(0.9,0.6,0.1) (0.9,0.4,0.0) (0.8,0.3,0.1)
Impaired joint mobility	(1.0,0.2,0.0) (0.8,0.4,0.1) (0.9,0.5,0.1)	(1.0,0.3,0.1) (0.9,0.4,0.0) (0.9,0.1,0.1)	(0.8,0.4,0.1) (0.8,0.4,0.1) (0.9,0.3,0.1)
Pain relief during rest	(0.8,0.3,0.3) (0.7,0.5,0.2) (0.8,0.2,0.1)	(0.6,0.2,0.3) (0.8,0.5,0.1) (0.7,0.5,0.2)	(0.7,0.5,0.1) (0.8,0.4,0.2) (0.8,0.5,0.2)
Annular or oval scaly rashes	(0.0,0.3,1.0) (0.0,0.4,1.0) (0.1,0.3,0.9)	(0.0,0.4,0.9) (0.0,0.4,0.9) (0.0,0.3,1.0)	(0.1,0.5,0.9) (0.0,0.4,1.0) (0.1,0.5,0.9)
Pain in the smaller joints	(0.0,0.5,0.9) (0.1,0.4,1.0) (0.1,0.3,0.9)	(0.1,0.5,0.9) (0.1,0.4,0.9) (0.1,0.3,0.8)	(0.1,0.5,0.9) (0.0,0.4,0.8) (0.0,0.3,0.9)

The Truth value (T) represents the degree to which a symptom, such as pain is present in a patient. It is derived from the reported severity of the symptom and normalized using a fixed maximum scale. This allows for consistent comparison of symptom intensity across patients. The value is computed using the following formula: $T = \frac{\text{symptom severity}}{\text{max scale}}$. For instance, if a patient reports a pain score of 8 on a 10-point scale, the corresponding truth value would be: $T = \frac{8}{10} = 0.8$.

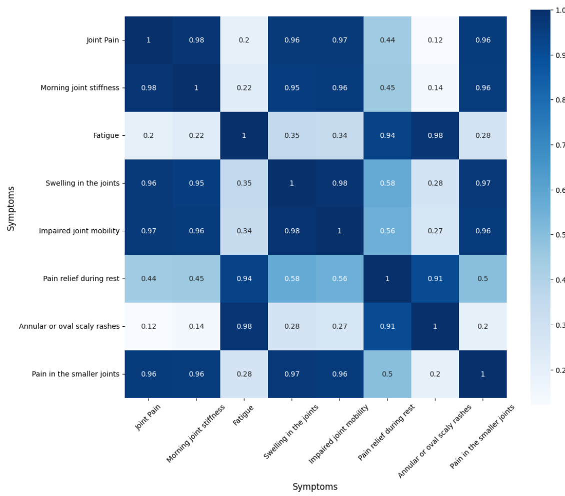
Table 6. Explanation for Choice of Indeterminacy Values

Clinical Condition	**Explanation**	**Indeterminacy**
Mild pain lasting for a short duration	May resolve on its own, not clearly a disorder	0.1
Pain with confirmed damage on imaging	Symptom aligns clearly with diagnostic results	0.2
Pain without diagnostic tests or detailed history	Insufficient clinical information for diagnosis	0.3
Severe pain reported, but imaging shows no abnormality	Symptom is intense, but not supported by objective evidence	0.4
Conflicting results from diagnostic tests	Inconsistent findings across investigations	0.5
Unexplained symptoms without clinical agreement	No identifiable cause	0.6

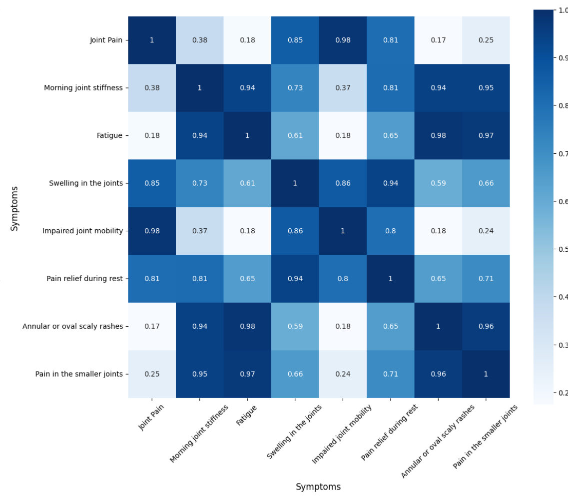
Falsity (F) values were not computed from a strict formula. Instead, they were selected to reflect domain intuition - especially in cases where high pain scores co-occurred with high uncertainty. In general, F tends to increase when symptom severity T is low and ambiguity I is low, but exceptions are allowed to reflect complex clinical judgments.

For Rheumatoid Arthritis Patient 1, the neutrosophic values for joint pain were derived from both symptom severity and clinical context. In the first sample, the patient reported a pain level of 10 out of 10, which was normalized using the formula, resulting in a truth value $T = 1.0$. An indeterminacy value of $I = 0.3$ was assigned due to the lack of detailed diagnostic history, indicating moderate ambiguity as per Table 6. The falsity value $F = 0.0$ reflected full confidence in symptom presence. In the second sample, the pain score decreased to 9 ($T = 0.9$), but conflicting diagnostic reports led to a higher indeterminacy value of $I = 0.4$ and a corresponding falsity of $F = 0.1$. In the third case, the pain level remained at 9, but supporting imaging results reduced the ambiguity to $I = 0.1$, with $F = 0.1$ to reflect minimal doubt in symptom presence.

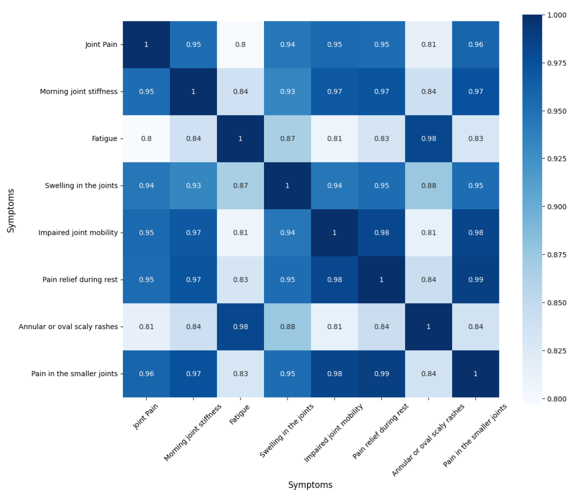
The correlation matrices shown below are generated with the help of the python implementation of Neutrosophic Refined sets. They reveal distinct patterns of symptom associations for each disorder.



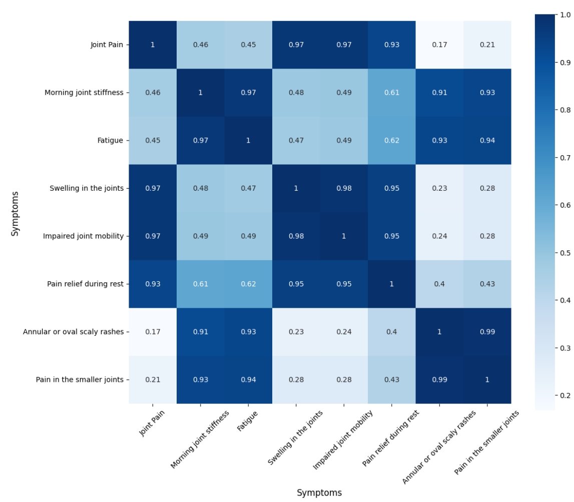
(a)



(b)



(c)



(d)

Figure 1. Heatmaps showing symptom correlations for (a) Rheumatoid Arthritis (b) Osteoarthritis (c) Lupus (d) Bursitis, where darker cells indicate stronger correlations.

From the results obtained in Figure 1, the following observations can be made:

- Individuals with Rheumatoid Arthritis commonly experience joint pain, especially in the morning, along with morning stiffness, joint swelling, fatigue, impaired joint mobility, and pain in smaller joints.
- Patients with Osteoarthritis often report joint pain and limited mobility, but symptoms like morning stiffness, fatigue, and swelling are less strongly correlated and typically less severe than in Rheumatoid Arthritis.

- In case of patients with lupus, fatigue is often accompanied by a characteristic round, scaly skin rash. The presence of other symptoms can vary, ranging from moderate to low.
- Bursitis typically manifests as significant joint pain, noticeable swelling, and difficulty in performing activities involving the affected joint. Pain in smaller joints may also be present, but to a lesser extent. Other symptoms are usually less pronounced.
- The presence of a round, scaly skin rash is a distinctive feature of Lupus and is less common in Rheumatoid Arthritis, Osteoarthritis, and Bursitis.

3.2. *Computing patient-disorder proximity using distance measures*

Consider a set of four patients - P1, P2, P3 and P4. T, I and F values for the four patients against the eight symptoms, recorded at four-month intervals over the span of a year along with the T, I and F values for symptoms versus disorders are tabulated

Table 7. Disorders vs Symptoms

	Rheumatoid Arthritis	**Osteoarthritis**	**Lupus**	**Bursitis**
Joint pain	(0.9,0.5,0.1)	(0.8,0.4,0.2)	(0.7,0.5,0.1)	(0.9,0.1,0.0)
Morning joint stiffness	(0.8,0.4,0.0)	(0.9,0.3,0.0)	(0.1,0.6,0.8)	(0.1,0.4,0.8)
Fatigue	(0.9,0.3,0.2)	(0.1,0.2,0.9)	(0.9,0.5,0.3)	(0.2,0.3,0.9)
Swelling in the joints	(0.7,0.2,0.1)	(0.7,0.1,0.2)	(0.7,0.2,0.0)	(0.8,0.3,0.2)
Impaired joint mobility	(0.8,0.5,0.1)	(0.8,0.4,0.3)	(0.0,0.4,0.9)	(0.7,0.2,0.0)
Pain relief during rest	(0.0,0.4,0.8)	(0.1,0.5,0.9)	(0.1,0.3,0.8)	(0.9,0.6,0.2)
Annular or oval scaly rashes	(0.1,0.3,0.9)	(0.2,0.4,0.8)	(0.8,0.1,0.2)	(0.0,0.1,0.6)
Pain in the smaller joints	(0.7,0.1,0.1)	(0.1,0.3,0.7)	(0.0,0.5,0.7)	(0.2,0.3,0.8)

Table 8. Patients vs Symptoms

	P1	**P2**	**P3**	**P4**
Joint pain	(0.7,0.3,0.1)	(0.9,0.4,0.0)	(0.7,0.3,0.2)	(0.8,0.4,0.1)
	(0.6,0.4,0.2)	(0.8,0.2,0.1)	(0.9,0.5,0.0)	(0.8,0.3,0.2)
	(0.9,0.1,0.1)	(0.9,0.2,0.1)	(0.9,0.1,0.1)	(0.9,0.2,0.0)
Morning joint stiffness	(0.6,0.2,0.3)	(0.7,0.1,0.2)	(0.0,0.2,0.9)	(0.0,0.5,0.7)
	(0.7,0.4,0.0)	(0.9,0.3,0.1)	(0.2,0.2,0.9)	(0.0,0.3,0.8)
	(0.7,0.3,0.1)	(0.6,0.5,0.3)	(0.1,0.4,0.7)	(0.1,0.4,0.8)
Fatigue	(0.5,0.5,0.0)	(0.2,0.4,0.9)	(0.7,0.5,0.1)	(0.1,0.2,0.9)
	(0.7,0.6,0.1)	(0.0,0.3,0.9)	(0.8,0.5,0.2)	(0.2,0.4,0.8)
	(0.8,0.3,0.1)	(0.0,0.2,0.7)	(0.9,0.1,0.2)	(0.0,0.3,0.9)
Swelling in the joints	(0.9,0.3,0.1)	(0.8,0.3,0.0)	(0.8,0.4,0.1)	(0.9,0.5,0.)
	(0.7,0.4,0.2)	(0.8,0.2,0.1)	(0.7,0.5,0.0)	(0.9,0.4,0.2)
	(0.6,0.3,0.2)	(0.9,0.2,0.3)	(0.8,0.1,0.2)	(0.7,0.2,0.3)
Impaired joint mobility	(0.8,0.3,0.1)	(0.9,0.4,0.1)	(0.0,0.3,0.9)	(0.8,0.4,0.0)
	(0.9,0.2,0.0)	(0.7,0.5,0.1)	(0.0,0.2,0.8)	(0.7,0.1,0.3)
	(0.7,0.3,0.2)	(0.8,0.1,0.0)	(0.1,0.2,0.9)	(0.9,0.1,0.1)
Pain relief during rest	(0.1,0.3,0.9)	(0.1,0.2,0.8)	(0.0,0.1,0.9)	(0.7,0.2,0.1)
	(0.2,0.4,0.8)	(0.0,0.5,0.8)	(0.1,0.4,0.7)	(0.9,0.3,0.1)
	(0.0,0.2,0.9)	(0.1,0.4,0.9)	(0.0,0.3,0.8)	(0.9,0.2,0.2)
Annular or oval scaly rashes	(0.0,0.4,0.8)	(0.2,0.3,0.9)	(0.9,0.2,0.1)	(0.0,0.3,0.7)
	(0.3,0.1,0.8)	(0.0,0.2,0.7)	(0.7,0.1,0.2)	(0.1,0.2,0.9)
	(0.1,0.2,0.7)	(0.1,0.4,0.9)	(0.9,0.3,0.0)	(0.2,0.2,0.8)
Pain in the smaller joints	(0.8,0.2,0.0)	(0.1,0.2,0.8)	(0.1,0.4,0.9)	(0.2,0.3,0.8)
	(0.9,0.4,0.1)	(0.2,0.5,0.8)	(0.0,0.3,0.7)	(0.1,0.4,0.8)
	(0.9,0.3,0.0)	(0.0,0.2,0.9)	(0.0,0.2,0.9)	(0.1,0.3,0.7)

Using the Python implementation along with the T, I and F values from the tables - Tables 7 and 8, the proximity of each patient to the four musculoskeletal disorders is calculated. Figure 2 illustrates the results obtained using four distance measures of Neutrosophic Refined Sets. The disorder corresponding to the minimum distance indicates the most likely diagnosis for each patient. Based on this analysis, it is concluded that patients P1, P2, P3, and P4 are diagnosed with Rheumatoid Arthritis, Osteoarthritis, Lupus, and Bursitis, respectively.

	Rheumatoid Arthritis	Osteoarthritis	Lupus	Bursitis
P1	8.9	16.3	23.4	22.6
P2	14.4	8.4	23.3	15.1
P3	23.8	23.6	8.3	22.9
P4	23.1	15.9	23.4	7.4

(a)

	Rheumatoid Arthritis	Osteoarthritis	Lupus	Bursitis
P1	0.124	0.226	0.325	0.314
P2	0.2	0.117	0.324	0.21
P3	0.331	0.328	0.115	0.318
P4	0.321	0.221	0.325	0.103

(b)

	Rheumatoid Arthritis	Osteoarthritis	Lupus	Bursitis
P1	3.627	6.461	8.85	8.727
P2	5.91	3.397	8.908	5.909
P3	9.247	9.087	3.639	8.892
P4	9.026	6.314	8.973	3.141

(c)

	Rheumatoid Arthritis	Osteoarthritis	Lupus	Bursitis
P1	0.05	0.09	0.123	0.121
P2	0.082	0.047	0.124	0.082
P3	0.128	0.126	0.051	0.124
P4	0.125	0.088	0.125	0.044

(d)

Figure 2. Patient-disorder proximity scores using distance measures - (a) Hamming distance (b) Normalized Hamming distance (c) Euclidean distance (d) Normalized Euclidean distance.

3.3. *Analyzing general symptom trends across disorders with interactive visualization*

Consider four sets of three patients - Patient 1, Patient 2, and Patient 3 - each group of patients diagnosed with one of the four musculoskeletal disorders. The recorded T, I and F values represent the degrees of presence or severity of each disorder.

The values presented in tables 2, 3, 4 and 5, reflect symptom severity and these values are correlated to the values in Table 9 to generate interactive visualizations. These visual tools enhance interpretability by highlighting the relative weight or contribution of each symptom to the respective disorder, thereby supporting clinical insight and comparative analysis across disorders.

The correlated values are further transformed using the Min-Max scaling technique to standardize their range for visual representation. This transformation ensures that all values lie within a uniform scale of 1 to 10, facilitating consistent comparison across different symptoms and disorders. The scaling is performed using the following formula:

$$X = \left\{ \left[\left(\frac{X - X_{\min}}{X_{\max} - X_{\min}} \right) \times 9 \right] + 1 \right\} \tag{8}$$

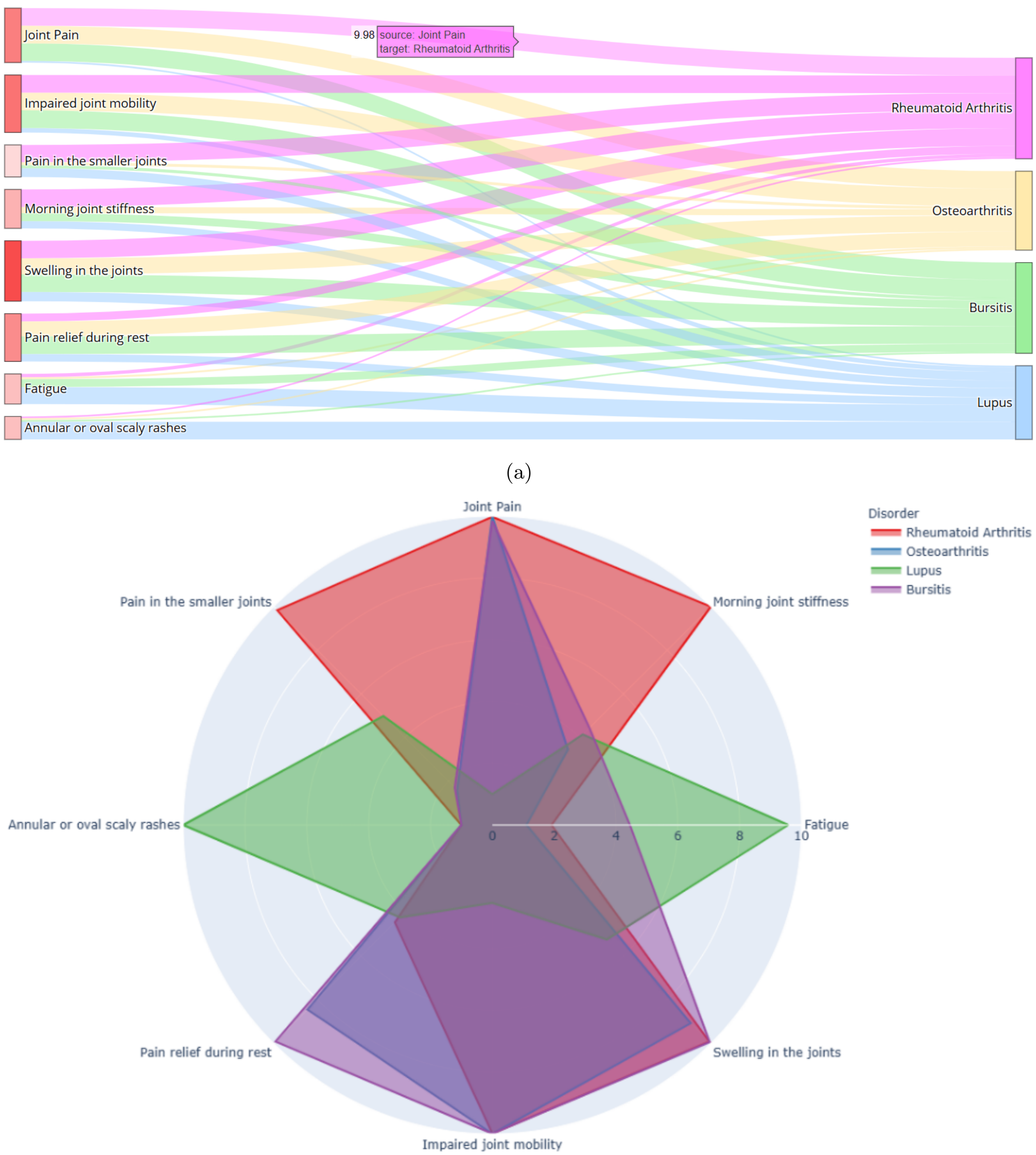
Here, X represents the original correlated value, while $X_{\mathtt{min}}$ and $X_{\mathtt{max}}$ denote the minimum and maximum values within the entire set of correlation scores, respectively.

Table 9. Disorder trend

	Patient 1	**Patient 2**	**Patient 3**
Rheumatoid Arthritis	(0.9,0.5,0.1)	(0.9,0.4,0.0)	(1.0,0.3,0.2)
Osteoarthritis	(0.8,0.4,0.2)	(0.9,0.3,0.0)	(0.7,0.1,0.2)
Lupus	(0.7,0.5,0.1)	(0.9,0.5,0.3)	(0.7,0.2,0.0)
Bursitis	(0.9,0.5,0.0)	(0.8,0.6,0.2)	(0.7,0.2,0.1)

The interactive charts in Figure 3 were generated using the Plotly library in Python and the python implementation of NRS especially that of correlation measure was used. The normalized correlation values serve as the input for generating these interactive charts. Plotly is a powerful open-source graphing library that enables the creation of high-quality, interactive visualizations. Its flexibility and extensive support for various chart types - such as heatmaps, scatter plots, and 3D surface plots - make it especially suitable for presenting complex multi-dimensional data.

In these visualizations, a value of 1 typically signifies that the symptom is either barely noticeable or almost completely absent in the individual being assessed. Conversely, a value of 10 represents the symptom's most intense or pronounced manifestation within the given context, enabling clear interpretation of symptom severity across disorders.



(b)

Figure 3. Visualization of symptom trends across musculoskeletal disorders using (a) a Sankey diagram to depict the strength of symptom-disorder associations, and (b) a radar chart to compare the relative prominence of each symptom among the disorders.

4. Conclusion

This study presents a comprehensive approach for analyzing and diagnosing musculoskeletal disorders using correlation and distance measures of Neutrosophic Refined Sets, implemented in Python. The proposed methodology encompasses three core components: first, the classification of disorders based on symptom patterns; second, the computation of distances between individual patient profiles and disorder-specific symptom sets; and third, the generation of informative visualizations that offer deeper insights into general symptom trends and disorder differentiation.

Overall, this work effectively integrates NRS theory with quantitative analysis, providing a robust and flexible implementation for both disease characterization and clinical decision support. The fusion of uncertainty modeling with correlation and distance-based computations not only enhances interpretability but also paves the way for scalable, data-driven diagnostic systems in healthcare. In conclusion, this work benefits the researchers who are deeply interested in exploring Neutrosophic Sets, their variations and particularly NRS, and their practical implementation in real-world scenarios. In future, the proposed framework can be extended to include medical imaging data or physiological signals alongside symptom profiles to improve diagnostic precision, particularly in complex disorders.

Supplementary Material

1. For Python implementation and illustrated examples: GitHub Link
2. Live Interactive Sankey Diagram: Click here
3. Live Interactive Radar Chart: Click here

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