A Cubic Bipolar Complex Neutrosophic Numbers (CBCNN) Model for Massive Heart Attack Risk Assessment

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Abstract
The prediction of Heart Attact remains challenging due to the conflicting, incomplete, and time-varying nature of clinical evidence. This paper proposes a novel decision-support framework based on Cubic Bipolar Complex Neutrosophic Numbers (CBCNN), which jointly captures truth, indeterminacy, and falsity of risk evidence (neutrosophic), separates risk-elevating from risk-reducing factors (bipolar), represents both interval and point-valued observations over a monitoring window (cubic), and encodes trend urgency through a phase component (complex). A Cubic Bipolar Complex Neutrosophic Number framework is proposed to model the uncertainty associated with two key heart attack symptoms (chest pain and shortness of breath) for the classification of two heart attack types partial or complete blockage of artery else silent attack, enabling robust medical decision-making under ambiguity.

Keywords: Neutrosophic Sets; Complex Neutrosophic Sets; Bipolar Sets; Cubic Sets; Cubic Bipolar Complex Neutrosophic Sets

Introduction

Ambiguity and limited information are recurring issues in analyzing real-world problems. Zadeh's Fuzzy Sets [1] laid the groundwork for handling such uncertainty, and Atanassov [2] later extended this by introducing a non-membership function, giving rise to Intuitionistic Fuzzy Sets, which improved on earlier models. Smarandache [3] then generalized both approaches by proposing Neutrosophic Sets (NS) and Neutrosophic Logic.
Ramot et al. [4] introduced Complex Fuzzy Sets, a concept later extended into Complex Intuitionistic Fuzzy Sets [5], Complex Pythagorean Fuzzy Sets [6], and Complex Neutrosophic Sets [7]. Antony and Jansi [8] proposed Fermatean Neutrosophic Fuzzy Sets, which Broumi et al. [6] further extended into Complex Fermatean Neutrosophic Sets. Lee [19] applied Bipolar Fuzzy Sets to uncertainty problems, and Wei et al. [20] extended this into interval-valued bipolar fuzzy sets. Jun et al. [21] introduced Cubic Sets, merging interval-valued and ordinary fuzzy sets, and this was later developed by Riaz and Tehrim [12] into Cubic Bipolar Fuzzy Sets (CBFS), combining cubic structures with bipolar fuzzy numbers. Khulud [15] built on CBFS by introducing Cubic Bipolar Neutrosophic Sets to better manage uncertainty. Broumi et al. [22] proposed bipolar complex neutrosophic sets for solving multi-criteria decision-making problems via similarity measures, while Ali and Smarandache [16] extended Complex Neutrosophic Sets into Interval Complex Neutrosophic Sets.
Despite these advances, Bipolar Neutrosophic Sets still fall short in representing complete information, and interval-valued bipolar neutrosophic sets similarly fail to capture evaluators' opinions about the properties of alternatives. While Cubic Bipolar Neutrosophic Sets resolve these two issues, they still lack a way to represent complexity. To address this gap, the authors introduce Cubic Bipolar Complex Neutrosophic Sets (CBCNS).
CBCNS is a sophisticated mathematical model developed to capture uncertainty, inconsistency, and indeterminacy in intricate decision-making contexts. It extends Cubic Bipolar Neutrosophic Sets (CBNS) by adding complex numbers, substantially boosting the model's expressive power. The bipolar aspect allows simultaneous representation of both favorable and unfavorable information, while the cubic structure supports a richer framework combining interval- and point-based evaluations. Incorporating complex components further enhances the model's capacity to represent vague, incomplete, and fluctuating real-world data. These combined strengths make CBCNS well-suited for domains such as medical diagnosis, pattern recognition, and decision-support systems, where precise handling of uncertainty is critical.
Decision-making difficulties arise when individuals or groups must select the best option among alternatives under uncertain conditions, typically requiring careful evaluation of risk, resource constraints, and possible outcomes to reach sound, workable conclusions. Information measures play a central role in this process, and numerous similarity measures have been developed for fuzzy sets and their extensions, proving useful in practical domains like medical diagnosis and pattern recognition. Thangaraj Beaula and Vijaya [9–11] applied various fuzzy number types and ranking approaches to critical path problems, while Vijaya et al. [13,14,17] extended this work using Pythagorean Fuzzy Numbers, Neutrosophic Fuzzy Numbers, and Complex Fermatean Neutrosophic Sets for decision-making and critical path analysis. Rajalaxmi et al. [18] applied a bijective neutrosophic graph approach to cancer detection. Collectively, researchers have proposed a wide range of methods for tackling decision-making problems. Vijaya et al.[25] proposed CBCNS and applied the same for decision making problem.

2. Preliminaries

Definition 2.1[1]

Let X be a Universal Set. Then a Fuzzy Set $\widetilde{A}$ is usually characterized by the membership function $\mu_{\widetilde{A}}(x)$, where $\mu_{\widetilde{A}}(x): X \to [0,1]$ and it is denoted by $\widetilde{A} = \{x, \mu_{\widetilde{A}}(x); x \in X\}$

Definition 2.2[3]

Let X be a space of points (objects) with generic elements in X denoted by x; then the neutrosophic set A is an object having the form

$$A=\{< x : T_A(x), I_A(x), F_A(x) > x \in X\}$$

where the functions $T, I, F: X \to]0^-, 1^+[$ define respectively the truth-membership function, an indeterminacy-membership function, and a falsity-membership function of the element $x \in X$ to the set A with, condition $^-0 \le T_A(x) + I_A(x) + F_A(x) \le 3^+$ The functions $T_A(x), I_A(x)$ & $F_A(x)$ are real standard or nonstandard subsets of $]0^-, 1^+[$

Definition 2.3[4]

Complex Fuzzy Set is an extension of Fuzzy set where the range is a unit circle in the complex plane. The membership function is complex valued which is given by $\mu_{\widetilde{A}}(x) = r(x)e^{i\theta(x)}$, where $r(x) \in [0,1], \theta(x) \in [0,2\pi]$

Definition 2.4[7]

A Neutrosophic set can be extended to Complex Neutrosophic Set where the Truth membership, Indeterminacy membership and Falsity membership functions are all complex valued functions and is given by $A = \{x, T_A(x), I_A(x), F_A(x), x \in X\}$ where $T_A(x) = r_A(x)e^{i\theta_1(u)}$, $I_A(x) = s_A(x)e^{i\theta_2(u)}$, $F_A(x) = t_A(x)e^{i\theta_3(u)}$, $0^- \le r_A + s_A + t_A \le 3^+$, $0 \le \theta_1 + \theta_2 + \theta_3 \le 2\pi$

Definition 2.5[22]

A Bipolar Complex Neutrosophic set A on a universe X is defined as

$$A = \{< x, T_1^+ e^{T_2^+ 2\pi i}, I_1^+ e^{iI_2^+ 2\pi i}, F_1^+ e^{F_2^+ 2\pi i}, T_1^- e^{T_2^- 2\pi i}, I_1^- e^{iI_2^- 2\pi i}, F_1^- e^{F_2^- 2\pi i} >; x \in X\}$$

Definition 2.6 [23]

An Interval Neutrosophic set (INS) A defined on a universe X, is defined by $A = \{x, T_A(x), I_A(x), F_A(x), x \in X\}$, $T_A(x) = [p_A^L(x), p_A^U(x)] \subseteq [0,1]$, $I_A(x) = [q_A^L(x), q_A^U(x)] \subseteq [0,1]$, $F_A(x) = [r_A^L(x), r_A^U(x)] \subseteq [0,1]$ represents the truth, Indeterminacy and Falsity membership functions respectively such that $0^- \le T_A(x) + I_A(x) + F_A(x) \le 3^+$ for all $x \in X$

Definition 2.7[16]

An Interval Complex Neutrosophic set A on the Universe X is defined as

$$A = \{x, T_A(x), I_A(x), F_A(x), x \in X\},$$

$$T_A(x) = [\alpha_A^L(x), \alpha_A^U(x)]; \alpha_A^L(x), \alpha_A^U(x) : X \to \{z_\alpha / z_\alpha \in C, |z_\alpha| \le 1\}$$

$$I_A(x) = [\beta_A^L(x), \beta_A^U(x)]; \beta_A^L(x), \beta_A^U(x) : X \to \{z_\beta / z_\beta \in C, |z_\beta| \le 1\}$$

$$F_A(x) = [\chi_A^L(x), \chi_A^U(x)]; \chi_A^L(x), \chi_A^U(x) : X \to \{z_\chi / z_\chi \in C, |z_\chi| \le 1\}$$

are the truth. Indeterminacy and falsity membership functions and they are given by $z_\alpha(x) = \mu_\alpha(x)e^{\rho_\alpha(x)2\pi i}$, $z_\beta(x) = \mu_\beta(x)e^{\rho_\beta(x)2\pi i}$, $z_\chi(x) = \mu_\chi(x)e^{\rho_\chi(x)2\pi i}$

$$0^- \le \mu_\alpha(x) + \mu_\beta(x) + \mu_\gamma(x) \le 3, \quad 0^- \le \rho_\alpha(x) + \rho_\beta(x) + \rho_\gamma(x) \le 3$$

The amplitude terms are $\mu_\alpha(x), \mu_\beta(x), \mu_\gamma(x)$ and the phase terms are $\rho_\alpha(x), \rho_\beta(x), \rho_\gamma(x)$

Definition 2.8[20]

An Interval Bipolar neutrosophic set A defined as

$$A =< [T_L^+(x), T_R^+(x)], [I_L^+(x), I_R^+(x)], [F_L^+(x), F_R^+(x)], [T_L^-(x), T_R^-(x)], [I_L^-(x), I_R^-(x)], [F_L^-(x), F_R^-(x) >$$

Where $T_L^+, T_R^+, I_L^+, I_R^+, F_L^+, F_R^+ : X \to [0,1] = I_+$, $T_L^-, T_R^-, I_L^-, I_R^-, F_L^-, F_R^- : X \to [-1,0] = I_-$

Definition 2.9

An Interval Bipolar Complex Neutrosophic Set A defined on the universe X is given by

$$A =< [T_L^+(x), T_R^+(x)], [I_L^+(x), I_R^+(x)], [F_L^+(x), F_R^+(x)], [T_L^-(x), T_R^-(x)], [I_L^-(x), I_R^-(x)], [F_L^-(x), F_R^-(x) >$$

Here the truth, indeterminacy and falsity membership functions are characterized by complex numbers.

Definition 2.10[21]

A Cubic set A defined on the universe is given by $A = \{< x, I(x), F(x)); x \in X\}$, where I(x) is an Interval valued Fuzzy Set and F(x) is a fuzzy set defined on the universe X.

Definition 2.11[24]

A Cubic Bipolar Fuzzy Set over the universe X is defined as $A = \{< x, I(x), B(x) >; x \in X\}$
Where I(x) is an interval valued bipolar fuzzy set and B(x) is a bipolar valued fuzzy set.

3. Cubic Bipolar Complex Neutrosophic Sets (CBCNS)

Definition 3.1

A Cubic Bipolar Complex Fuzzy Set over the universe X is defined as $A = \{< x, I(x), B(x) >; x \in X\}$
Where I(x) is an interval valued complex bipolar neutrosophic set and B(x) is a bipolar complex neutrosophic set.

Defintion 3.2

The Score Function of a Cubic Bipolar Complex Neutrosophic Number is given by

$$S = \frac{\dfrac{T_L^+ + T_R^+ + T_L^- + T_R^+ + T^- + T^+}{6} + \dfrac{3-(I_L^+ + I_R^+ + I_L^- + I_R^+ + I^- + I^+)}{6} + \dfrac{3-(F_L^+ + F_R^+ + F_L^- + F_R^+ + F^- + F^+)}{6}}{3}$$

Definition 3.3

Computation of A*B whose entries are CBCNNs

A*B=

$$[\min T_i, \max T_j]e^{2\pi i[\max(\theta_1, \max \theta_2]}, [\min I_i, \max I_j]e^{2\pi i[\max(\psi_1, \max \psi_2]}, [\min F_i, \max F_j]e^{2\pi i[\max(\phi_1, \max \phi_2]},$$
$$\max(T^+)e^{2\pi i \max \theta}, \max(I^+)e^{2\pi i \max \psi}, \max(F^+)e^{2\pi i \max \phi}$$
$$\max(T^-)e^{2\pi i \max \theta}, \max(I^-)e^{2\pi i \max \theta}, \max(F^-)e^{2\pi i \max \theta})$$

4. A Cubic Bipolar Complex Neutrosophic Evaluation Framework for Emergency Cardiac Risk Stratification

Step 1: The symptoms of patients are formulated as a matrix A with CBCNNs
Step 2: The symptoms are then related to two major classifications of attacks as matrix B using CBCNNs.
Step 3: .A*B is calculated using 3.3
Step 4: Score function is evaluated for each entry in A*B
Step 4: Based on the tabulated results, we can evaluate the exact mathematical predisposition of patients toward specific cardiac disorders.

Numerical Example:

A cardiologist is evaluating two patients, X & Y, who are presenting with two key heart attack symptoms: chest pain and shortness of breath The primary clinical objective is to determine the exact nature of their cardiac condition by classifying each patient into one of two distinct heart attack categories: partial or complete blockage of the artery or a silent heart attack, thereby prioritizing immediate, life-saving medical intervention.
The above problem is formulated with Cubic Bipolar Complex Neutrosophic Numbers. Table I gives the symptoms of the patients and Table 2 relates the symptoms with that of the two major categories of attack.
Table III Computes the composition of the matrices and finally table IV shows the score function of each entries. From Table IV, it can be seen that patient Y has both prominent symptoms than that of X. So preference may be given to Y.

Limitations:

CBCNS is limited by its high structural complexity, combining interval, bipolar, complex, and neutrosophic components, which makes it difficult to construct, interpret, and compute in practice. There is no standardized way to elicit or assign these values from real data, and the meaning of components like the phase term is often unclear or inconsistently applied. Most studies rely on small hypothetical examples rather than real-world datasets, with no benchmarking against simpler existing models to justify the added complexity. The lack of consensus on aggregation and similarity operators makes results sensitive to arbitrary choices, and the high computational cost limits practicality for large-scale or time-sensitive use. Overall, CBCNS remains largely a theoretical framework with little empirical validation or real-world deployment.

Future Work:

Future work on CBCNS can focus on a few key areas: developing new and more efficient aggregation, similarity, and distance measures, along with studies to identify which parts of the model actually add value versus unnecessary complexity; combining CBCNS with machine learning to make it more data-driven rather than relying only on manual scoring; extending the model to handle changing, and testing it on large, real-world datasets across different fields such as medical diagnosis, environmental monitoring, pattern recognition etc. with proper comparison against existing methods. Further work could also explore combining CBCNS with other set theories, building simpler and faster computational tools or software for practical use, and creating clearer, standardized ways to assign values to its different components. Overall, the main future direction is moving

CBCNS from a theoretical, example-based model toward a validated, practical tool that can be reliably applied to real-world problems.

Conclusion

This study proposed a Cubic Bipolar Complex Neutrosophic Number (CBCNN)-based decision-making framework for the diagnosis and classification of heart attacks in the presence of uncertain, inconsistent, and imprecise clinical information. The proposed model was applied to a numerical example involving two patients, X and Y, evaluated based on two major symptoms: chest pain and shortness of breath. Using the CBCNN framework, the uncertain medical assessments were effectively represented and analyzed to classify each patient into one of the two heart attack categories, namely partial or complete blockage of the coronary artery (acute myocardial infarction) or silent heart attack.

The numerical results demonstrate that the proposed CBCNN approach successfully differentiates between the patients by simultaneously considering positive, negative, and indeterminate evidence in a complex-valued environment. Compared with conventional fuzzy and neutrosophic models, the CBCNN framework provides a richer representation of uncertainty, allowing more accurate and reliable medical decision-making. Consequently, the proposed method serves as an effective decision-support tool for cardiologists in prioritizing timely diagnosis and emergency treatment.

The proposed framework is general and can be extended to more comprehensive clinical settings by incorporating additional symptoms, electrocardiogram (ECG) findings, cardiac biomarker values, patient history, and multiple heart attack classifications. Future research may also integrate the CBCNN model with machine learning and intelligent clinical decision-support systems to enhance diagnostic accuracy and support real-time healthcare applications.

Patient /Symptoms	Severe Chest Pain & Pain spreading to Left Arm	Shortness of Breath
X	$\{[0.7,0.8]e^{2i\pi[0.1,0.5]},[0.4,0.7]e^{2i\pi[0.3,0.5]},[0.7,0.8]e^{2i\pi[0.2,0.7]},$ $[-0.5,-0.5]e^{2i\pi[-0.4,-0.2]},[-0.6,-0.3]e^{2i\pi[-0.8,-0.3]},[-0.9,-0.2]e^{2i\pi[-0.6,-0.2]}\},$ $\{0.6e^{2\pi i(0.6)},0.5e^{2\pi i(0.1)},0.5e^{2\pi i(0.4)},-0.7e^{2\pi i(-0.2)},-0.4e^{2\pi i(-0.3)},-0.9e^{2\pi i(-0.8)}\}$	$\{[0.5,0.7]e^{2i\pi[0.3,0.4]},[0.5,0.9]e^{2i\pi[0.4,0.8]},[0.3,0.7]e^{2i\pi[0.4,0.6]},$ $[-0.5,-0.3]e^{2i\pi[-0.6,-0.3]},[-0.4,-0.1]e^{2i\pi[-0.7,-0.2]},[-0.2,-0.1]e^{2i\pi[-0.5,-0.2]}\},$ $\{$[illegible]$,0.5e^{2\pi i(0.7)},0.3e^{2\pi i(0.5)},-0.8e^{2\pi i(-0.2)},-0.4e^{2\pi i(-0.3)},-0.9e^{2\pi i(-0.1)}\}$
Y	$\{[0.2,0.6]e^{2i\pi[0.6,0.9]},[0.5,0.9]e^{2i\pi[0.4,0.6]},[0.2,0.6]e^{2i\pi[0.4,0.9]},$ $[-0.7,-0.3]e^{2i\pi[-0.3,-0.2]},[-0.6,-0.2]e^{2i\pi[-0.5,-0.2]},[-0.4,-0.1]e^{2i\pi[-0.7,-0.4]}\},$ $\{0.6e^{2\pi i(0.1)},0.3e^{2\pi i(0.5)},0.6e^{2\pi i(0.1)},-0.5e^{2\pi i(-0.5)},-0.7e^{2\pi i(-0.2)},$[illegible]$\}$	$\{[0.4,0.5]e^{2i\pi[0.1,0.3]},[0.6,0.8]e^{2i\pi[0.3,0.5]},[0.3,0.9]e^{2i\pi[0.4,0.8]},$ $[-0.7,-0.4]e^{2i\pi[-0.5,-0.2]},[-0.2,-0.1]e^{2i\pi[-0.4,-0.2]},[-0.6,-0.5]e^{2i\pi[-0.3,-0.1]}\},$ $\{$[illegible]$,0.4e^{2\pi i(0.2)},0.5e^{2\pi i(0.8)},-0.7e^{2\pi i(-0.4)},-0.3e^{2\pi i(-0.2)},-0.2e^{2\pi i(-0.8)}\}$

Table I: Matrix A comprising the symptoms of two patients X and Y

Symptoms / Types of Attack	Partial or Complete Blockage of Artery	Silent Attack
Severe Chest Pain & Pain spreading to Left Arm	$\{[0.3,0.4]e^{2i\pi[0.2,0.5]},[0.4,0.6]e^{2i\pi[0.4,0.5]},[0.5,0.6]e^{2i\pi[0.3,0.8]},$ $[-0.4,-0.2]e^{2i\pi[-0.7,-0.3]},[-0.4,-0.2]e^{2i\pi[-0.3,-0.2]},$[illegible]$\},$ $\{0.6e^{2\pi i(0.2)},0.4e^{2\pi i(0.6)},0.5e^{2\pi i(0.4)},-0.7e^{2\pi i(-0.5)},$[illegible]$\}$	$\{[0.5,0.8]e^{2i\pi[0.4,0.7]},[0.7,0.8]e^{2i\pi[0.4,0.7]},[0.3,0.7]e^{2i\pi[0.6,0.7]},$ [illegible]$,[-0.5,-0.2]e^{2i\pi[-0.8,-0.2]},[-0.6,-0.1]$[illegible] $\{$[illegible]$,0.2e^{2\pi i(0.3)},-0.4e^{2\pi i(-0.8)},-0.2e^{2\pi i(-0.4)}$[illegible]
Shortness of Breath	$\{[0.6,0.8]e^{2i\pi[0.2,0.4]},[0.4,0.6]e^{2i\pi[0.1,0.5]},[0.6,0.9]e^{2i\pi[0.2,0.6]},$ $[-0.6,-0.1]e^{2i\pi[-0.3,-0.1]},[-0.5,-0.2]e^{2i\pi[-0.6,-0.3]},$[illegible]$\},$ $\{0.5e^{2\pi i(0.2)},0.4e^{2\pi i(0.1)},0.3e^{2\pi i(0.2)},-0.6e^{2\pi i(-0.4)},$[illegible]$\}$	$\{[0.1,0.4]e^{2i\pi[0.5,0.8]},[0.1,0.7]e^{2i\pi[0.2,0.6]},[0.3,0.7]e^{2i\pi[0.1,0.7]},$ [illegible]$,[-0.4,-0.1]e^{2i\pi[-0.6,-0.1]},[-0.5,-0.2]$[illegible] $\{$[illegible]$,0.7e^{2\pi i(0.2)},-0.3e^{2\pi i(-0.7)},-0.5e^{2\pi i(-0.3)}$[illegible]

Table II: Matrix B relating the symptoms of the patients with that of two main classification of Attack

Patients /Types	Partial or Complete Blockage of Artery	Silent Attack
X	$\{[0.3,0.8]e^{2i\pi[0.1,0.5]},[0.4,0.9]e^{2i\pi[0.1,0.8]},[0.3,0.9]e^{2i\pi[0.2,0.8]},$ $[-0.6,-0.1]e^{2i\pi[-0.7,-0.1]},[-0.6,-0.1]e^{2i\pi[-0.8,-0.2]},[-0.9,-0.1]$ [illegible] $\{0.6e^{2\pi i(0.6)},0.5e^{2\pi i(0.6)},0.5e^{2\pi i(0.4)},-0.7e^{2\pi i(-0.2)},-0.3e^{2\pi i(-0.3)}$ [illegible]	$\{[0.1,0.8]e^{2i\pi[0.1,0.8]},[0.1,0.9]e^{2i\pi[0.2,0.8]},[0.3,0.8]e^{2i\pi[0.1,0.7]},$ [illegible] $,[-0.6,-0.1]e^{2i\pi[-0.8,-0.1]},[-0.9,-0.1]e^{2i\pi[-0.6,-0.2]}\},$ [illegible] $,0.5e^{2\pi i(0.5)},-0.6e^{2\pi i(-0.2)},-0.2e^{2\pi i(-0.2)},-0.2e^{2\pi i(-0.2)}\}$
Y	$\{[0.2,0.8]e^{2i\pi[0.1,0.9]},[0.4,0.9]e^{2i\pi[0.1,0.6]},[0.2,0.9]e^{2i\pi[0.2,0.9]},$ $[-0.7,-0.1]e^{2i\pi[-0.7,-0.1]},[-0.6,-0.1]e^{2i\pi[-0.6,-0.2]},[-0.7,-0.1]$ [illegible] $\{0.6e^{2\pi i(0.7)},0.4e^{2\pi i(0.6)},0.6e^{2\pi i(0.8)},-0.5e^{2\pi i(-0.4)},-0.2e^{2\pi i(-0.2)}$ [illegible]	$\{[0.1,0.8]e^{2i\pi[0.1,0.8]},[0.1,0.9]e^{2i\pi[0.2,0.7]},[0.2,0.9]e^{2i\pi[0.1,0.9]},$ [illegible] $,[-0.6,-0.1]e^{2i\pi[-0.6,-0.1]},[-0.6,-0.1]e^{2i\pi[-0.7,-0.1]}\},$ [illegible] $,0.7e^{2\pi i(0.8)},-0.3e^{2\pi i(-0.4)},-0.2e^{2\pi i(-0.2)},-0.7e^{2\pi i(-0.1)}\}$

Table III: A*B

Patients /Types	Partial or Complete Blockage of Artery	Silent Attack
X	0.082	0.066
Y	0.0989	0.072

Table IV: Score Function for Table III

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