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Approximation of Interval Type-2 Neutrosophic Bézier Surface Model for Uncertainty Data

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ABSTRACT

Some data will be wasted during the data collection process due to uncertain criteria or noise information. In the context of the interval type-2 neutrosophic set (IT2NS) theory's ability to handle uncertain data, this study will use geometric models to illustrate how all data will be processed. IT2NS is a generalization of the type-1 neutrosophic set, interval type-2 fuzzy set, and intuitionistic fuzzy set. This study will show how to use the approximation approach to visualize the interval type-2 neutrosophic Bézier surface (IT2NBS) model. However, the existence of truth, indeterminacy, and falsity membership functions in neutrosophic features makes the model challenging to visualize. Apart from that, the attributes of IT2NS have an upper and lower bound, which makes it difficult. Using the IT2NS theory, this study will first introduce an interval type-2 neutrosophic control net (IT2NCN) to build the model. The IT2NBS models will be represented by blending the IT2NCN and the Bernstein basis function. Afterward, the truth, indeterminacy, and falsity memberships of the IT2NBSs are approximated for the mean, upper and lower bounds of the IT2NCN. A review of the algorithm used to create the IT2NBS approximation models will wrap up the study. Fortunately, the results of this study will yield a predictive model that is used in some medical applications or bathymetry data collection that involves the uncertainty data problem in the data collection.

1. Introduction

Zadeh [1] developed fuzzy set (FS) theory as a generalization of the classical concept of a set and a proposition to account for fuzziness (degree of truth) as expressed in natural or human language as stated in [2,3]. Although type-1 FS (T1FS) is commonly used and has an associated meaning of uncertainty, previous research has demonstrated that T1FS only partially depicts uncertainty and may be unable to handle or decrease the effects of uncertainties found in some real-world applications mentioned in [4]. To address this issue, Zadeh [5] proposed expanding his earlier T1FS theory to include the type-2 fuzzy set (T2FS) theory, which can handle uncertainties that T1 finds difficult to manage due to T2FS's fuzzy membership grades. A few research have demonstrated that

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the outcome of a T2FS may be better than that of a T1FS that was conducted by [6-11]. Due to the computational cost of using a generic T2FS, most individuals now exclusively use interval T2FSs. The computations for interval T2FSs are manageable and practicable as emphasized in [4].

Atanassov [12] presented intuitionistic fuzzy sets (IFSs), accounting for membership and non-membership grades. Smarandache [13] expanded IFSs to neutrosophic sets (NSs) with truth, indeterminacy, and falsity membership functions to capture the indeterminacy membership grade. Wang *et al.* [14] suggested the concept of a single-valued neutrosophic set (SVNS) as a solution to ambiguous, indeterminate, and incoherent data. Wang *et al.* [15] created interval type-2 neutrosophic sets (IT2NSs) to quantify improbability and ambiguity better as stated in [16]. Touqeer *et al.* [17] proposed interval type-2 trapezoidal neutrosophic numbers via operations. According to the study, an interval neutrosophic set is defined and used the same way as an interval type-2 neutrosophic set.

The data set is an important component for presenting the surfaces. If there is any ambiguity in a data collection, it must be resolved before being used to create surface models. Using an IT2NS to create geometric models is an effective technique to address the issue of making data obvious when there is uncertainty. Some research that has been conducted to ensure that curves and surfaces in geometric modeling with uncertainty data are easily usable as in [18-21]. There have been various academic works on fuzzy geometry modeling such as [22-28]. Rosli and Zulkifly [29-34] recently proposed type-1 neutrosophic geometric modeling for B-spline curve approximation, B-spline surface approximation, 3-dimensional quartic Bézier curve approximation model, bicubic Bezier surface approximation, 3-dimensional B-spline surface approximation model, and interval neutrosophic cubic Bézier curve approximation model. Meanwhile, this paper will use the approximation approach to offer an interval type-2 neutrosophic Bézier surface.

The main objective of this research is to create a modeling of an interval type-2 neutrosophic Bézier surface (IT2NBS) approximation model. Before building the IT2NBS, the IT2NS, and its properties must be used to define the interval type-2 neutrosophic control net relation (IT2NCNR). The Bernstein basis function is used with these control nets to create models of IT2NBSs, which are then visualized using an approximation method. The following is how this paper is organized. Section 1 provided some background information regarding the study. Section 2 explains the fundamental concepts of IT2NS, interval type-2 data points (IT2DPs), and IT2NCNR. Section 3 describes how to use IT2NCNR to approximate the IT2NBS. Section 4 includes a numerical example and a visualization of IT2NBS. The surface properties are also shown, along with the method by which they were created. Finally, part 5 will bring this study to a conclusion.

2. Basic Properties

This part aims to introduce the IT2NDPs and IT2NCPs that refer to a dataset, with the IT2NDPs being regarded as IT2NCPs to represent the IT2NBCs. Thus, before discussing IT2NDPs, it is necessary to define IT2NS, interval type-2 neutrosophic relation (IT2NS), and interval type-2 neutrosophic point (IT2NP). Wang *et al.* [35] introduced the essential notion of IT2NS. Later, Tas and Topal [36,37] inspired the definition of IT2NCPs for neutrosophic points. Furthermore, the concept of IT2NDPs comes from a study by Zakaria *et al.* [38-40] on type-2 fuzzy data points in geometric modeling and an interval type-2 trapezoidal neutrosophic numbers by Touqeer *et al.* [17].

Definition 1 [35]
Let X be the universal set that elements in X denoted as x. An interval type-2 neutrosophic set (IT2NS) A is expressed by the truth membership function T_A, indeterminacy membership function I_A, and false membership function F_A. Where $x \in X, T_A(x), I_A(x), F_A(x) \subseteq [0,1]$.

When X is continuous, an IT2NS A can be expressed as

$$A = \int_X \langle T(x), I(x), F(x) \rangle / x, x \in X \tag{1}$$

When X is discrete, an IT2NS A can be expressed as

$$A = \sum_{i=1}^{n} \langle T(x_i), I(x_i), F(x_i) \rangle / x_i, x_i \in X \tag{2}$$

Definition 2 [35]
Suppose X and Y be a non-empty crisp set. $R(X,Y)$ denoted as interval type-2 neutrosophic relation (IT2NR) in a subset of product space $X \times Y$ and containing the truth membership function $T_R(x,y)$, indeterminacy membership function $I_R(x,y)$ and false membership function $F_R(x,y)$ where $x \in X$ and $y \in Y$, and $T_R(x,y), I_R(x,y), F_R(x,y) \subseteq [0,1]$.

Definition 3 [34]
Suppose A in the space of $x \in X$ is an interval type-2 neutrosophic point (IT2NP) and $x = \{x_i\}$ is a set of IT2NPs where there exists $T_A(x) = [\sup(T_A), \inf(T_A)] : X \to [0,1]$ defining as the supremum and infimum of truth membership, $I_A(x) = [\sup(I_A), \inf(I_A)] : X \to [0,1]$ defining as the supremum and infimum of indeterminacy membership and $F_A(x) = [\sup(F_A), \inf(F_A)] : X \to [0,1]$ defining as the supremum and infimum of false membership where

$$T_A(x) = \begin{cases} 0 & \text{if } x_i \notin X \\ a \in (0,1) & \text{if } x_i \hat{\in} X \\ 1 & \text{if } x_i \in X \end{cases} \tag{3}$$

$$I_A(x) = \begin{cases} 0 & \text{if } x_i \notin X \\ b \in (0,1) & \text{if } x_i \hat{\in} X \\ 1 & \text{if } x_i \in X \end{cases} \tag{4}$$

$$F_A(x) = \begin{cases} 0 & \text{if } x_i \notin X \\ c \in (0,1) & \text{if } x_i \hat{\in} X \\ 1 & \text{if } x_i \in X \end{cases} \tag{5}$$

Definition 4 [34]
Let $A=\{x|x \text{ interval type-2 neutrosophic point}\}$ and $D=\{D_i|D_i \text{ data point}\}$ is a set of interval type-2 neutrosophic data points with $D_i \in D \subset X$, where X is a universal set and $T_A(D_i)=[\sup(T_A),\inf(T_A)]:D\to[0,1]$ for truth membership function which defined as $T_A(D_i)=1$, $I_A(D_i)=[\sup(I_A),\inf(I_A)]:D\to[0,1]$ for indeterminacy membership function defined as $I_A(D_i)=1$, $F_A(D_i)=[\sup(F_A),\inf(F_A)]:D\to[0,1]$ for falsity membership function defined as $F_A(D_i)=1$ and formulated by $D=\{(D_i,T_A(D_i),I_A(D_i)F_A(D_i)|D_i\in\sim)\}$. Thus,

$$T_A(D_i)=\begin{cases} 0 & \text{if } D_i \notin X \\ a\in(0,1) & \text{if } D_i \hat{\in} X \\ 1 & \text{if } D_i \in X \end{cases} \tag{6}$$

$$I_A(D_i)=\begin{cases} 0 & \text{if } D_i \notin X \\ b\in(0,1) & \text{if } D_i \hat{\in} X \\ 1 & \text{if } D_i \in X \end{cases} \tag{7}$$

$$F_A(D_i)=\begin{cases} 0 & \text{if } D_i \notin X \\ c\in(0,1) & \text{if } D_i \hat{\in} X \\ 1 & \text{if } D_i \in X \end{cases} \tag{8}$$

For all i and the three memberships, $D_i=\langle D_i^L,D_i,D_i^R\rangle$ with $D_i^L=\langle D_i^{LL},D_i^L,D_i^{LR}\rangle$ where D_i^{LL}, D_i^L and D_i^{LR} are left-left, left, and left-right of IT2NDP and $D_i^R=\langle D_i^{RL},D_i^R,D_i^{RR}\rangle$ where D_i^{RL}, D_i^R, and D_i^{RR} are right-left, right, and right-right of IT2NDP respectively. Figure 1 illustrates this with the green triangle representing truth, the blue triangle representing indeterminacy, and the red triangle representing falsehood memberships. The dashed triangle for each membership at the values $[D^L,D,D^R]$ represented the type-1 neutrosophic set for each membership. The upper and lower boundaries for each membership are given by values $[D^{LL},D,D^{RR}]$ and $[D^{LR},D,D^{RL}]$, respectively.

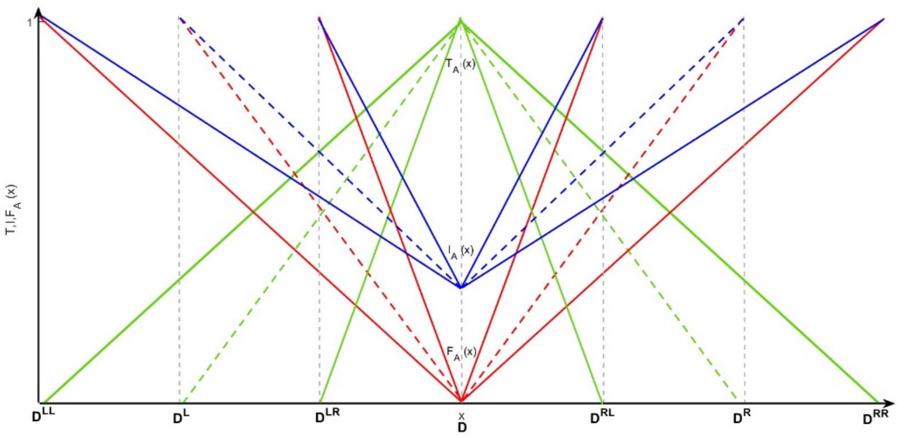

Fig. 1. Interval type-2 neutrosophic data points for truth, indeterminacy, and membership degrees

2.1 Interval Type-2 Neutrosophic Control Net Relation (IT2NCPR)

The geometry of a spline surface can only be described by all the points required to build the surface. This is what the word "control net" means. The control net plays an important role in developing, controlling, and manufacturing smooth surfaces. The interval type-2 neutrosophic control point relation (IT2NCPR) is defined in this section by first using the notion of an interval type-2 neutrosophic set from the research published by [24,25] in the following way:

Definition 5 [34]
Let $\hat{R}$ be an IT2NPR, then IT2NCPR is defined as a set of point $n+1$ that indicates the positions and coordinates of a location is used to describe the curve and is denoted by

$$\begin{aligned} \hat{P}_i^T &= \left\{ \hat{p}_0^T, \hat{p}_1^T, \dots, \hat{p}_n^T \right\} \\ \hat{P}_i^I &= \left\{ \hat{p}_0^I, \hat{p}_1^I, \dots, \hat{p}_n^I \right\} \\ \hat{P}_i^F &= \left\{ \hat{p}_0^F, \hat{p}_1^F, \dots, \hat{p}_n^F \right\} \end{aligned} \tag{9}$$

where $\hat{P}_i^T$, $\hat{P}_i^I$ and $\hat{P}_i^F$ are interval type-2 neutrosophic control points for membership truth, indeterminacy and i is one less than n. Thus, the IT2NCNR can be defined as follows.

Definition 6
Let $\hat{P}$ be an IT2NCPR, and then define an IT2NCNR as points n and m for $\hat{P}$ in their direction, and it can be denoted by $\hat{P}_{i,j}$ that represents the locations of points used to describe the surface and may be written as

$$\hat{P}_{i,j}^{T,I,F} = \begin{bmatrix} \hat{P}_{0,0} & \hat{P}_{0,1} & \cdots & \hat{P}_{0,m} \\ \hat{P}_{1,0} & \hat{P}_{1,1} & \cdots & \hat{P}_{1,m} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{P}_{n,0} & \hat{P}_{n,1} & \cdots & \hat{P}_{n,m} \end{bmatrix} \tag{10}$$

3. Approximation of an Interval Type-2 Neutrosophic Bézier Surface (IT2NBS)

Surface is a vector value function with two parameters that govern how the plane is projected into the Euclidean three-dimensional frame as mentioned in [21]. This type of mapping is known as surface mapping. The tensor product technique is a bidirectional curve construction method that employs basic functions as well as geometric coefficients. The IT2NCNR and **Definition 1** are used to build the IT2NBS, which is then used to incorporate the Bézier blending function into a geometric model. Following that, it investigates the characteristics of the IT2NBS model. IT2NBS, which stands for approximation approach, can be represented mathematically as follows:

Definition 7

Let $\hat{P}^{T,I,F}_{i,j} = \begin{bmatrix} \hat{P}_{0,0} & \hat{P}_{0,1} & \cdots & \hat{P}_{0,m} \\ \hat{P}_{1,0} & \hat{P}_{1,1} & \cdots & \hat{P}_{1,m} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{P}_{n,0} & \hat{P}_{n,1} & \cdots & \hat{P}_{n,m} \end{bmatrix}$

where $i = 0,1,...,n$ and $j = 0,1,...,m$ is IT2NCNR. Cartesian Bézier surface is given by:

$$\begin{aligned} \widetilde{BS}^T(u,w) &= \sum_{i=0}^{n}\sum_{j=0}^{m} \hat{P}^T_{i,j} C^n_i(u) C^m_j(w) \\ \widetilde{BS}^I(u,w) &= \sum_{i=0}^{n}\sum_{j=0}^{m} \hat{P}^I_{i,j} C^n_i(u) C^m_j(w) \\ \widetilde{BS}^F(u,w) &= \sum_{i=0}^{n}\sum_{j=0}^{m} \hat{P}^F_{i,j} C^n_i(u) C^m_j(w) \end{aligned} \tag{11}$$

where $C^n_i(u)$ and $C^m_j(w)$ are the Bernstein functions in the u and w parametric directions.

$$\begin{aligned} C^n_i(u) &= \binom{n}{i} u^i (1-u)^{n-i} \qquad (0)^0 \equiv 1 \\ C^m_j(w) &= \binom{m}{j} w^j (1-w)^{m-j} \qquad (0)^0 \equiv 1 \\ &\text{with} \\ \binom{n}{i} &= \frac{n!}{i!(n-1)!} \qquad (0)^0 \equiv 1 \\ \binom{m}{j} &= \frac{n!}{j!(m-1)!} \qquad (0)^0 \equiv 1 \end{aligned} \tag{12}$$

3.1 Properties of Interval Type-2 Neutrosophic Bézier Surface (IT2NBS) Approximation

The surface-blending functions employ the Bernstein basis, therefore the Bézier surface has the same features. The primary characteristics of IT2NBS are as follows:

i. The degree of IT2NBS is always one less than the control net vertices in the direction that it is being measured in, regardless of the parametric direction.
ii. Control net vertices in a particular direction are two fewer than the continuity of the IT2NBS in that direction.
iii. The IT2NBS will conform to the IT2NCNR of the shape.
iv. The only points that coincide between the IT2NCNR and the IT2NBS that it generates are the corner points.
v. The IT2NBS is protected from outside interference by the IT2NCNR's convex hull.
vi. The IT2NBS does not show any signs of the quality known as variation declining. Undefined and unknown information exists on the variation-diminishing feature of bivariant IT2NBS.
vii. The IT2NBS does not change in any way when subjected to an affine transformation.

4. Visualization Of Interval Type-2 Neutrosophic Bézier Surface (IT2NBS)

This section illustrates the IT2NBS approximation model for the truth, indeterminacy, and falsity membership functions. This section will conclude with a demonstration of the combining of all memberships in one axis and a discussion of an algorithm for creating the IT2NBS. Let's examine **the matrixes below** as a dataset representing IT2NCN. Based on Definition 4 and Figure 1, $\hat{P}_{3,3}$, $\hat{P}^{L}_{3,3}$, $\hat{P}^{LL}_{3,3}$, $\hat{P}^{R}_{3,3}$, $\hat{P}^{RR}_{3,3}$, $\hat{P}^{RL}_{3,3}$ and $\hat{P}^{LR}_{3,3}$ as the mean, left, left-left, right, right, right-left and left-right 4×4 IT2NCN for Bézier surfaces with the degree of polynomial $n=3$ for the values $\langle T,F,I\rangle$.

$$\hat{P}_{3,3}=\begin{bmatrix}\langle(-17,17);0.4,0.7,0.2\rangle & \langle(-17,7);0.9,0.3,0.1\rangle & \langle(-17,-7);0.4,0.4,0.5\rangle & \langle(-17,-17);0.6,0.5,0.2\rangle\\ \langle(-7,17);0.6,0.4,0.3\rangle & \langle(-7,7);0.8,0.2,0.3\rangle & \langle(-7,-7);0.5,0.5,0.3\rangle & \langle(-7,-17);0.7,0.4,0.2\rangle\\ \langle(7,17);0.6,0.2,0.5\rangle & \langle(7,7);0.8,0.4,0.1\rangle & \langle(7,-7);0.5,0.7,0.1\rangle & \langle(7,-17);0.5,0.3,0.5\rangle\\ \langle(17,17);0.7,0.3,0.3\rangle & \langle(17,7);0.4,0.6,0.3\rangle & \langle(17,-7);0.4,0.6,0.3\rangle & \langle(17,-17);0.7,0.4,0.2\rangle\end{bmatrix}$$

$$\hat{P}^{L}_{3,3}=\begin{bmatrix}\langle(-19,15);0.4,0.7,0.2\rangle & \langle(-19,5);0.9,0.3,0.1\rangle & \langle(-19,-9);0.4,0.4,0.5\rangle & \langle(-19,-19);0.6,0.5,0.2\rangle\\ \langle(-9,15);0.6,0.4,0.3\rangle & \langle(-9,5);0.8,0.2,0.3\rangle & \langle(-9,-9);0.5,0.5,0.3\rangle & \langle(-9,-19);0.7,0.4,0.2\rangle\\ \langle(5,15);0.6,0.2,0.5\rangle & \langle(5,5);0.8,0.4,0.1\rangle & \langle(5,-9);0.5,0.7,0.1\rangle & \langle(5,-19);0.5,0.3,0.5\rangle\\ \langle(15,15);0.7,0.3,0.3\rangle & \langle(15,5);0.4,0.6,0.3\rangle & \langle(15,-9);0.4,0.6,0.3\rangle & \langle(15,-19);0.7,0.4,0.2\rangle\end{bmatrix}$$

$$\hat{P}^{LR}_{3,3}=\begin{bmatrix}\langle(-21,13);0.4,0.7,0.2\rangle & \langle(-21,3);0.9,0.3,0.1\rangle & \langle(-21,-11);0.4,0.4,0.5\rangle & \langle(-21,-21);0.6,0.5,0.2\rangle\\ \langle(-11,13);0.6,0.4,0.3\rangle & \langle(-11,3);0.8,0.2,0.3\rangle & \langle(-11,-11);0.5,0.5,0.3\rangle & \langle(-11,-21);0.7,0.4,0.2\rangle\\ \langle(3,13);0.6,0.2,0.5\rangle & \langle(3,3);0.8,0.4,0.1\rangle & \langle(3,-11);0.5,0.7,0.1\rangle & \langle(3,-21);0.5,0.3,0.5\rangle\\ \langle(13,13);0.7,0.3,0.3\rangle & \langle(13,3);0.4,0.6,0.3\rangle & \langle(13,-11);0.4,0.6,0.3\rangle & \langle(13,-21);0.7,0.4,0.2\rangle\end{bmatrix}$$

$$\hat{P}^{LL}_{3,3}=\begin{bmatrix}\langle(-23,11);0.4,0.7,0.2\rangle & \langle(-23,1);0.9,0.3,0.1\rangle & \langle(-23,-13);0.4,0.4,0.5\rangle & \langle(-23,-23);0.6,0.5,0.2\rangle\\ \langle(-13,11);0.6,0.4,0.3\rangle & \langle(-13,1);0.8,0.2,0.3\rangle & \langle(-13,-13);0.5,0.5,0.3\rangle & \langle(-13,-23);0.7,0.4,0.2\rangle\\ \langle(1,11);0.6,0.2,0.5\rangle & \langle(1,1);0.8,0.4,0.1\rangle & \langle(1,-13);0.5,0.7,0.1\rangle & \langle(1,-23);0.5,0.3,0.5\rangle\\ \langle(11,11);0.7,0.3,0.3\rangle & \langle(11,1);0.4,0.6,0.3\rangle & \langle(11,-13);0.4,0.6,0.3\rangle & \langle(11,-23);0.7,0.4,0.2\rangle\end{bmatrix}$$

$$\hat{P}^{R}_{3,3}=\begin{bmatrix}\langle(-15,19);0.4,0.7,0.2\rangle & \langle(-15,9);0.9,0.3,0.1\rangle & \langle(-15,-5);0.4,0.4,0.5\rangle & \langle(-15,-15);0.6,0.5,0.2\rangle\\ \langle(-5,19);0.6,0.4,0.3\rangle & \langle(-5,9);0.8,0.2,0.3\rangle & \langle(-5,-5);0.5,0.5,0.3\rangle & \langle(-5,-15);0.7,0.4,0.2\rangle\\ \langle(9,19);0.6,0.2,0.5\rangle & \langle(9,9);0.8,0.4,0.1\rangle & \langle(9,-5);0.5,0.7,0.1\rangle & \langle(9,-15);0.5,0.3,0.5\rangle\\ \langle(19,19);0.7,0.3,0.3\rangle & \langle(19,9);0.4,0.6,0.3\rangle & \langle(19,-5);0.4,0.6,0.3\rangle & \langle(19,-15);0.7,0.4,0.2\rangle\end{bmatrix}$$

$$\hat{P}^{RL}_{3,3}=\begin{bmatrix}\langle(-13,21);0.4,0.7,0.2\rangle & \langle(-13,11);0.9,0.3,0.1\rangle & \langle(-13,-3);0.4,0.4,0.5\rangle & \langle(-13,-13);0.6,0.5,0.2\rangle\\ \langle(-3,21);0.6,0.4,0.3\rangle & \langle(-3,11);0.8,0.2,0.3\rangle & \langle(-3,-3);0.5,0.5,0.3\rangle & \langle(-3,-13);0.7,0.4,0.2\rangle\\ \langle(11,21);0.6,0.2,0.5\rangle & \langle(11,11);0.8,0.4,0.1\rangle & \langle(11,-3);0.5,0.7,0.1\rangle & \langle(11,-13);0.5,0.3,0.5\rangle\\ \langle(21,21);0.7,0.3,0.3\rangle & \langle(21,11);0.4,0.6,0.3\rangle & \langle(21,-3);0.4,0.6,0.3\rangle & \langle(21,-13);0.7,0.4,0.2\rangle\end{bmatrix}$$

$$\hat{P}^{RR}_{3,3}=\begin{bmatrix}\langle(-11,23);0.4,0.7,0.2\rangle & \langle(-11,13);0.9,0.3,0.1\rangle & \langle(-11,-1);0.4,0.4,0.5\rangle & \langle(-11,-11);0.6,0.5,0.2\rangle\\ \langle(-1,23);0.6,0.4,0.3\rangle & \langle(-1,13);0.8,0.2,0.3\rangle & \langle(-1,-1);0.5,0.5,0.3\rangle & \langle(-1,-11);0.7,0.4,0.2\rangle\\ \langle(13,23);0.6,0.2,0.5\rangle & \langle(13,13);0.8,0.4,0.1\rangle & \langle(13,-1);0.5,0.7,0.1\rangle & \langle(13,-11);0.5,0.3,0.5\rangle\\ \langle(23,23);0.7,0.3,0.3\rangle & \langle(23,13);0.4,0.6,0.3\rangle & \langle(23,-1);0.4,0.6,0.3\rangle & \langle(23,-11);0.7,0.4,0.2\rangle\end{bmatrix}$$

Figure 2-4 depicts the IT2NBSs, which comprises truth, indeterminacy, and falsity membership for each of their left and right footprints. Truth membership is represented by the green curves, indeterminacy by the blue curves, and falsehood by the red curves.

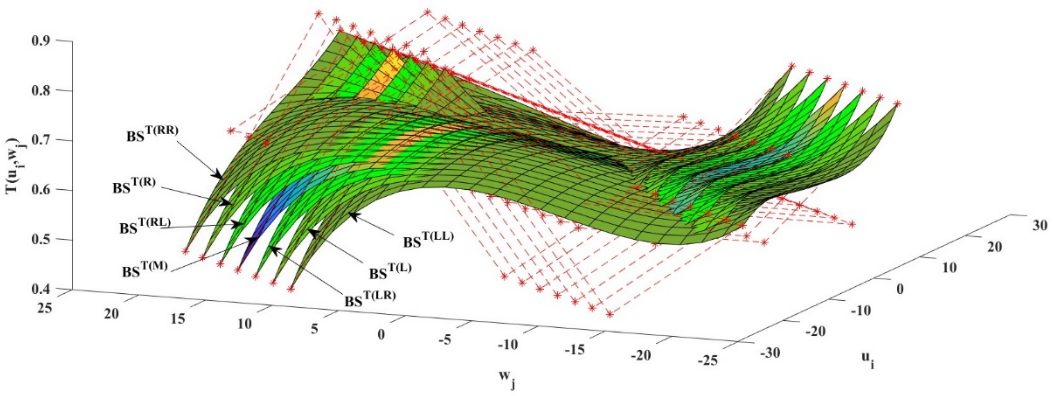

Fig. 2. IT2NBSs for truth membership with its respective IT2NCN

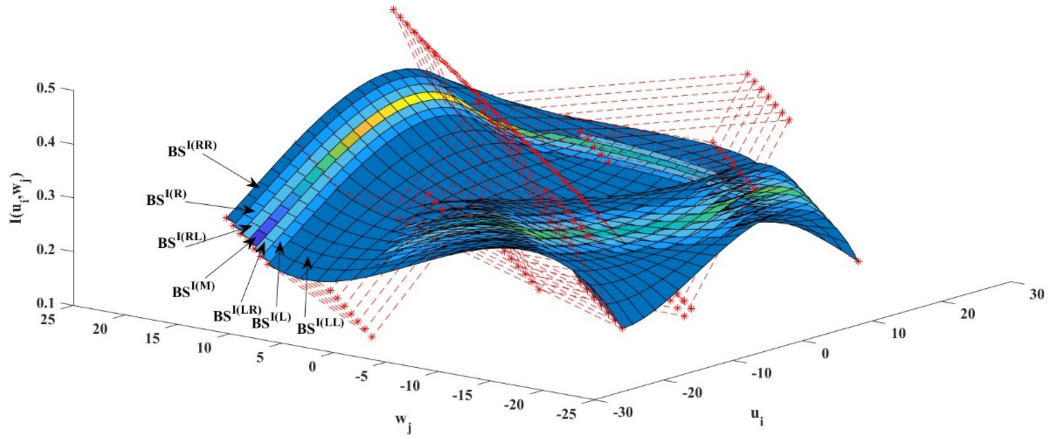

Fig. 3. IT2NBSs for indeterminacy membership with its respective IT2NCN

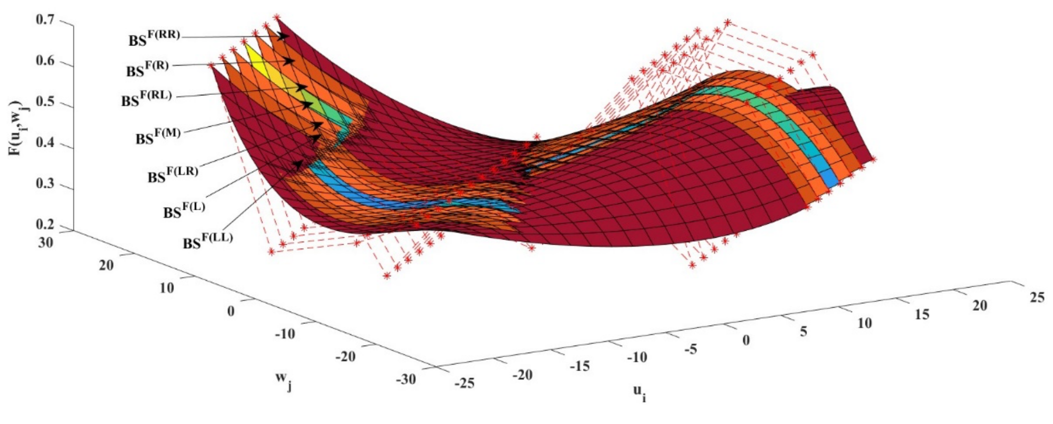

Fig. 4. IT2NBSs for falsity membership with its respective IT2NCN

Figure 5 displays the IT2NBSs with their respective IT2NCNs and memberships. Figure 6 at the end of this section shows how an algorithm for creating the IT2NBSs works.

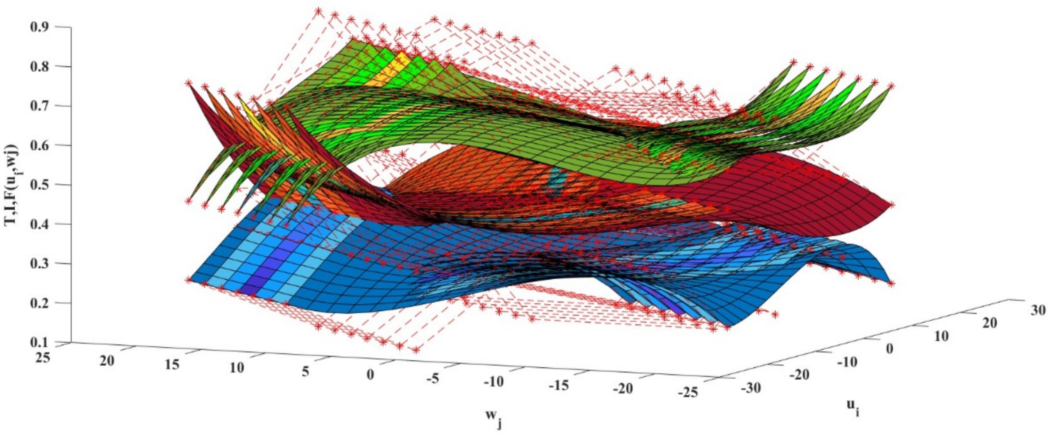

Fig. 5. IT2NBSs with their respective IT2NCNs and memberships

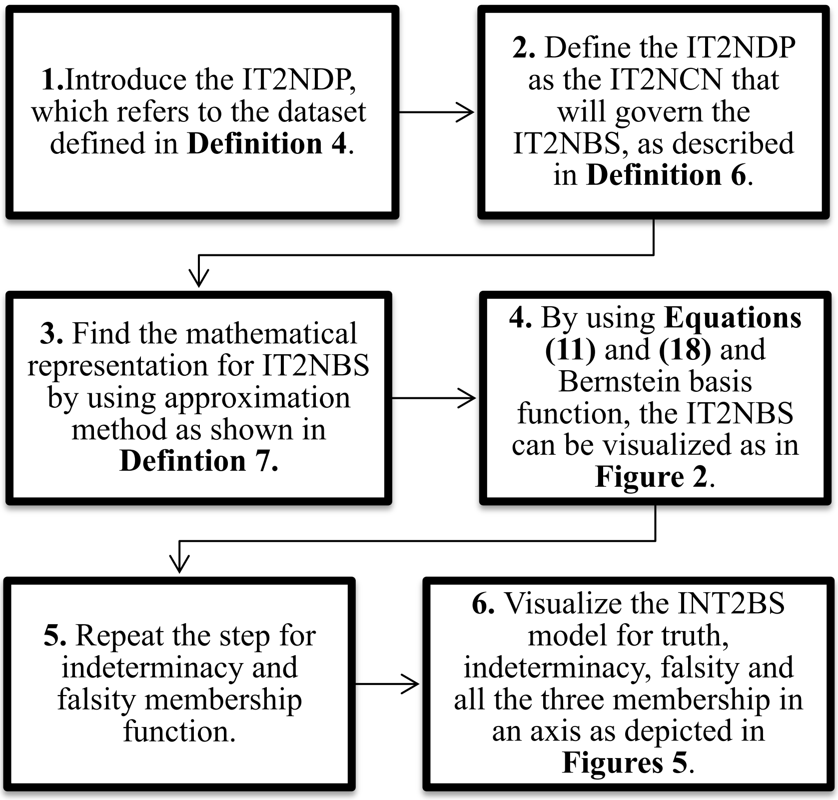

Fig. 6. An algorithm to create the IT2NBSs approximation models

5. Conclusion

This study proposed IT2NS principles for developing the IT2NCN, which governs IT2NBS behaviours. The model demonstrates how to display an uncertain dataset using IT2NS theory. This approach has the potential to make large contributions to fields with high levels of uncertainty, such as bathymetry data. Predictive models are utilized in a variety of medical applications, including cancer-level prediction, image-blurring detection, and catastrophe warning systems. This research can be expanded to incorporate more complex problems, particularly the type-2 neutrosophic set. Furthermore, different geometric models, such as B-spline and non-uniform rational B-spline (NURBS), could be used in future research to increase the study's visualization capabilities. Furthermore, this study can grow using surface modelling approaches or approximation methods.

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References

[1] Zadeh, Lotfi A. "Fuzzy sets." *Information and control* 8, no. 3 (1965): 338-353. https://doi.org/10.1016/S0019-9958(65)90241-X
[2] Pranevicius, Henrikas, Tadas Kraujalis, Germanas Budnikas, and Vytautas Pilkauskas. "Fuzzy rule base generation using discretization of membership functions and neural network." In *Information and Software Technologies: 20th International Conference, ICIST 2014, Druskininkai, Lithuania, October 9-10, 2014. Proceedings 20*, pp. 160-171. Springer International Publishing, 2014. https://doi.org/10.1007/978-3-319-11958-8_13
[3] Chiu, Stephen. "Extracting fuzzy rules from data for function approximation and pattern classification." *Fuzzy information engineering: A guided tour of applications* 9 (1997): 1-10.
[4] Mendel, Jerry M., and Hongwei Wu. "Uncertainty versus choice in rule-based fuzzy logic systems." In *2002 IEEE World Congress on Computational Intelligence. 2002 IEEE International Conference on Fuzzy Systems. FUZZ-IEEE'02. Proceedings (Cat. No. 02CH37291)*, vol. 2, pp. 1336-1341. IEEE, 2002. https://doi.org/10.1109/FUZZ.2002.1006698
[5] Zadeh, Lotfi Asker. "The concept of a linguistic variable and its application to approximate reasoning—I." *Information sciences* 8, no. 3 (1975): 199-249. https://doi.org/10.1016/0020-0255(75)90036-5
[6] Hagras, Hani A. "A hierarchical type-2 fuzzy logic control architecture for autonomous mobile robots." *IEEE Transactions on Fuzzy systems* 12, no. 4 (2004): 524-539. https://doi.org/10.1109/TFUZZ.2004.832538
[7] Liang, Qilian, and Jerry M. Mendel. "Interval type-2 fuzzy logic systems: theory and design." *IEEE Transactions on Fuzzy systems* 8, no. 5 (2000): 535-550. https://doi.org/10.1109/91.873577
[8] Melgarejo, Miguel A., Carlos Andrés Peña-Reyes, and Antonio García. "Computational model and architectural proposal for a hardware type-2 fuzzy system." In *Neural Networks and Computational Intelligence*, pp. 279-284. 2004.
[9] Melin, Patricia, and Oscar Castillo. "A new method for adaptive control of non-linear plants using type-2 fuzzy logic and neural networks." *International Journal of General Systems* 33, no. 2-3 (2004): 289-304. https://doi.org/10.1080/03081070310001633608
[10] Ozen, Turhan, and Jonathan Mark Garibaldi. "Investigating adaptation in type-2 fuzzy logic systems applied to umbilical acid-base assessment." In *Proceedings of 2003 European Symposium on Intelligent Technologies (EUNITE 2003)*, pp. 289-294. 2003. https://doi.org/10.1109/FUZZY.2004.1375536
[11] Wu, Dongrui, and Woei Wan Tan. "A type-2 fuzzy logic controller for the liquid-level process." In *2004 IEEE International Conference on Fuzzy Systems (IEEE Cat. No. 04CH37542)*, vol. 2, pp. 953-958. IEEE, 2004.
[12] Atanassov, Krassimir T., and Krassimir T. Atanassov. *Intuitionistic fuzzy sets*. Physica-Verlag HD, 1999. https://doi.org/10.1007/978-3-7908-1870-3
[13] Smarandache, Florentin. "Neutrosophic set-a generalization of the intuitionistic fuzzy set." *International journal of pure and applied mathematics* 24, no. 3 (2005): 287.
[14] Wang, Haibin, Florentin Smarandache, Yanqing Zhang, and Rajshekhar Sunderraman. *Single valued neutrosophic sets*. Infinite study, 2010.
[15] Wang H., Madiraju P., Sunderraman R. and Zhang Y.Q. Interval Neutrosophic Sets. *Department of Computer Science*, State University Atlanta, Georgia, USA. 2004.
[16] Ye, Jun. "Similarity measures between interval neutrosophic sets and their applications in multicriteria decision-making." *Journal of intelligent & fuzzy systems* 26, no. 1 (2014): 165-172. https://doi.org/10.3233/IFS-120724
[17] Touqeer, Muhammad, Rimsha Umer, Ali Ahmadian, and Soheil Salahshour. "A novel extension of TOPSIS with interval type-2 trapezoidal neutrosophic numbers using (α, β, γ)-cuts." *RAIRO-Operations Research* 55, no. 5 (2021): 2657-2683. https://doi.org/10.1051/ro/2021133
[18] Yamaguchi, Fujio. *Curves and surfaces in computer aided geometric design*. Springer Science & Business Media, 2012.
[19] Rogers, David F. *An introduction to NURBS: with historical perspective*. Elsevier, 2000.
[20] Farin, Gerald E. *Curves and surfaces for CAGD: a practical guide*. Morgan Kaufmann, 2002.
[21] Piegl, L., and W. Tiller. "The NURBS Book, Springer-Verlag." *New York* (1995). https://doi.org/10.1007/978-3-642-97385-7
[22] Jacas, Joan, Amadeu Monreal, and Jordi Recasens. "A model for CAGD using fuzzy logic." *International Journal of* Approximate *Reasoning* 16, no. 3-4 (1997): 289-308. https://doi.org/10.1016/S0888-613X(96)00124-7

[23] Wahab, Abdul Fatah, Jamaludin Md Ali, Ahmad Abdul Majid, and Abu Osman Md Tap. "Fuzzy set in geometric modeling." In *Proceedings. International Conference on Computer Graphics, Imaging and Visualization, 2004. CGIV 2004.*, pp. 227-232. IEEE, 2004.
[24] Wahab, A. F., Ali, J. M. and Majid, A. A. "Fuzzy geometric modeling." Sixth International Conference on Computer Graphics, *Imaging and Visualization,* 276-280. 2009. https://doi.org/10.1109/CGIV.2009.82
[25] Wahab, Abd Fatah, Jamaludin Md Ali, Ahmad Abd Majid, and Abu Osman Md Tap. "Penyelesaian Masalah Data Ketakpastian Menggunakan Splin-B Kabur." *Sains Malaysiana* 39, no. 4 (2010): 661-670.
[26] Jacas, Joan, Amadeu Monreal, and Jordi Recasens. "A model for CAGD using fuzzy logic." *International Journal of Approximate Reasoning* 16, no. 3-4 (1997): 289-308. https://doi.org/10.1016/S0888-613X(96)00124-7
[27] Bidin, Mohd Syafiq, Abd Fatah Wahab, Mohammad Izat Emir Zulkifly, and Rozaimi Zakaria. "Generalized Fuzzy Linguistic Bicubic B-Spline Surface Model for Uncertain Fuzzy Linguistic Data." *Symmetry* 14, no. 11 (2022): 2267. https://doi.org/10.3390/sym14112267
[28] Zakaria, Rozaimi, Abd Fatah Wahab, Isfarita Ismail, and Mohammad Izat Emir Zulkifly. "Complex uncertainty of surface data modeling via the type-2 fuzzy B-spline model." *Mathematics* 9, no. 9 (2021): 1054. https://doi.org/10.3390/math9091054
[29] Rosli, Siti Nur Idara Binti, and Mohammad Izat Emir Bin Zulkifly. "A Neutrosophic Approach for B-Spline Curve by Using Interpolation Method." *Neutrosophic Systems with Applications* 9 (2023): 29-40. https://doi.org/10.61356/j.nswa.2023.43
[30] Rosli, Siti Nur Idara, and Mohammad Izat Emir Zulkifly. "Neutrosophic Bicubic B-spline surface interpolation model for uncertainty data." *Neutrosophic Systems with Applications* 10 (2023): 25-34. https://doi.org/10.61356/j.nswa.2023.69
[31] Rosli, Siti Nur Idara, and Mohammad Izat Emir Zulkifly. "3-Dimensional quartic Bézier curve approximation model by using neutrosophic approach." *Neutrosophic Systems with Applications* 11 (2023): 11-21. https://doi.org/10.61356/j.nswa.2023.78
[32] Rosli, Siti Nur Idara, and Mohammad Izat Emir Zulkifly. "Neutrosophic Bicubic Bezier Surface ApproximationModel for Uncertainty Data." *Matematika* (2023): 281-291. https://doi.org/10.11113/matematika.v39.n3.1502
[33] Rosli, Siti Nur Idara, and Mohammadi Izati Emir iZulkifly. "Neutrosophic B-spline Surface Approximation Model for 3-Dimensional Data Collection." *Neutrosophic Sets and Systems* 63 (2024): 95-104.
[34] Rosli, Siti Nur Idara, and Mohammad Izat Emir Zulkifly Zulkifly. "Interval Neutrosophic Cubic Bézier Curve Approximation Model for Complex Data." *Malaysian Journal of Fundamental and Applied Sciences* 20, no. 2 (2024): 336-346. https://doi.org/10.11113/mjfas.v20n2.3240
[35] Wang, Haibin, Y-Q. Zhang, and Rajshekhar Sunderraman. "Truth-value based interval neutrosophic sets." In *2005 IEEE International Conference on Granular Computing*, vol. 1, pp. 274-277. IEEE, 2005. https://doi.org/10.1109/GRC.2005.1547284
[36] Tas, Ferhat, and Selçuk Topal. "Bezier curve modeling for neutrosophic data problem." *Neutrosophic Sets and Systems* 16 (2017): 3-5. https://doi.org/10.20944/preprints201704.0176.v1
[37] Topal, Selçuk, and Ferhat Tas. "Bezier surface modeling for neutrosophic data problems." *Neutrosophic Sets and Systems* 19 (2018): 19-23.
[38] Zakaria, Rozaimi, Abd Fatah Wahab, and R. U. Gobithaasan. "The Representative curve of type-2 fuzzy data point modeling." *Modern Applied Science* 7, no. 5 (2013): 60-71. https://doi.org/10.5539/mas.v7n5p60
[39] Zakaria, Rozaimi, Abd Wahab, and Rudrusamy U. Gobithaasan. "Normal type-2 fuzzy rational b-spline curve." *arXiv preprint arXiv:1304.7868* (2013). https://doi.org/10.1063/1.4887635
[40] Zakaria, Rozaimi, Abd Wahab, and Rudrusamy U. Gobithaasan. "Perfectly normal type-2 fuzzy interpolation B-spline curve." *arXiv preprint arXiv:1305.0001* (2013). https://doi.org/10.1063/1.4887635