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An Enhancement of Neutrosophic Exploratory Data Analysis Technique Using Hybrid Method

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A B S T R A C T

In this research, a Hybrid method is made between the Hanning and Hamming methods so that this method depends on granting new weights to combine the two methods, which are merged through an algorithm that depends on its classification on the numerical method (BFGS) and was applied to three types of neutrosophic data on this method.

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1. Introduction

In analyzing neutrosophic exploratory data, Hanning and Hamming windows are important windows in reducing uncertainty through a special algorithm for each method, which contributes to analyzing data in a way that is closer to reality. These windows are of great importance in eliminating distortions in data. In 2014, the researchers Prajoy Podder and et al. made a comparison between the performance of the Hanning, Hamming, and Blackman windows in terms of analysis [1].

In 2005, the researcher Julio Barros and others presented research on the use of the Hanning window in consensual analysis, in which the Hanning window was studied in the treatment of a large consensual stream [2]. In 2023, AST Mohamed et.al mentioned the comparison of the performance of some proposed smoothers in three types of Hannings and their application in forecasting. In 2023[12], Shaju, et al. proposed a neutrosophic trait index to explain the psychological concept of the anti-trait using refined neutrosophic sets [8]. In 2024, as a proposed technique in Neutrosophic Exploratory data analysis, Ahmed et.al introduced and implemented a method to detect and treat outliers and extremes, which could affect the results of the analysis [7]. In 2025, Khan and Krebs

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introduced a proposed technique to improve the existing neutrosophic structures to be more beneficial for researchers in their studies [6].

In this paper a proposed technique which will address the concept of hyper integrating two important techniques in exploratory data analysis, namely Hanning and Hamming. The proposed techniques have been applied on three sets of real data.

2. Algorithm of Hybrid Methods

1. Data entry: Reading the initial data as intervals (minimum and maximum).
2. Window weight calculation: Using the BFGS algorithm to estimate the weights w_1 (Hamming) and w_2 for the window (Hanning) such that: $w_1 + w_2 = 1$.
3. Then, the error is reduced or the accuracy of the results is increased (depending on the context). The BFGS algorithm is used to obtain the optimal weights in step (2), and it is formulated as follows:
   - Start with weights $\mathrm{w}_1$and w_2 using random values.
   - Problem definition: The Mean Squared Error (MSE) is calculated using the following equation: $\mathrm{MSE} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}\left(\mathrm{D}_{\mathrm{Acual}_{\mathrm{i}}} - \mathrm{D}_{\mathrm{Estimated}_{\mathrm{i}}}\right)^2$
   - Updating the weights using the equation: $w_i = w_{i_0} + \alpha \frac{\frac{1}{e_i}}{\sum_{j=1}\left(\frac{1}{e_i}\right)^2}, i = 1,2$

     Where α is the learning rate and $\mathrm{e_i}$ is the error value.
   - We repeat the steps to achieve the ideal weights.
4. Calculation of individual results: Multiply each segment by the Hamming weight and each segment by the Hanning weight, applying both windowing equations.
5. Calculating the hybrid score: by applying the equation below: $\mathrm{Hybrid} = \mathrm{w}_1\mathrm{hamming} + \mathrm{w}_2\mathrm{hanning}$
6. Output of results: Present the results as shown in tables 1 to 3.

3. Application

In this part, an application of the hybrid method, which combines the Hanning and Hamming windows has been applied on three types of real neutrosophic data. The first dataset pertains to COVID-19 in the Netherlands, covering a 30-day period from March 31 to April 30, 2020. These data were formed from an approximate mortality rate taken from Al-Mongi et al. 17 [3]. The second set of data represented the estimation of intervals for infant mortality rates for those under the age of five [4]. As for the third set of data, it consisted of real data related to the monthly minimum and maximum temperatures in Lahore, Pakistan, for the years 2016-2020 [5].

Data 1: represents a COVID-19 data belonging to the Netherlands of 30 days, which have been recorded from 31 March to 30 April 2020. This data had been formed of rough mortality rate taken from Almongy et al. [9]

Table 1. result of data 1 for Hybrid Method .4

No	Neutrosophic data	Optimal weights		Hamming	Hanning	Hybrid method
		$\mathrm{w}_{\mathrm{hamming}}$	$\mathrm{w}_{\mathrm{hanning}}$			
1	[14.918,15.66390]	0.07998	0.00000000	[1.19308, 1.25268]	0.00000000	[1.19308, 1.25268]
2	[10.056,11.18880]	0.09073	0.00000362	[0.91238, 1.01516]	[0.00003640, 0.00004050]	[0.91241640, 1.01520050]
3	[12.274,12.88770]	0.12249	0.00001433	[1.50349, 1.57857]	[0.00017589, 0.00018468]	[1.50366589, 1.57875468]
4	[10.289,10.80345]	0.17377	0.00003160	[1.78791, 1.87730]	[0.00032513, 0.00034139]	[1.78823513, 1.87764139]
5	[10.832,7.09900]	0.24218	0.00005466	[2.62329, 1.71924]	[0.00059208, 0.00038803]	[2.62388208, 1.71962803]
6	[7.099,7.45395]	0.32451	0.00008240	[2.30339, 2.41871]	[0.00058496, 0.00061421]	[2.30397496, 2.41932421]

7	[5.928, 6.22440]	0.41692	0.00011353	[2.47152, 2.59548]	[0.00067301, 0.00070662]	[2.47219301, 2.59618662]
8	[13.211,7.96800]	0.51508	0.00014661	[6.80480, 4.10419]	[0.00193698, 0.00116836]	[6.80673698, 4.10535836]
9	[7.968,8.36640]	0.61441	0.00018008	[4.89562, 5.14082]	[0.00143488, 0.00150638]	[4.89705488, 5.14232638]
10	[7.584,7.96320]	0.71026	0.00021237	[5.38661, 5.65578]	[0.00161062, 0.00169113]	[5.38822062, 5.65747113]
11	[5.555,5.83275]	0.79814	0.00024198	[4.43367, 4.65639]	[0.00134420, 0.00141137]	[4.43501420, 4.65780137]
12	[6.027,6.32835]	0.87395	0.00026753	[5.26730, 5.53065]	[0.00161180, 0.00169239]	[5.26891180, 5.53234239]
13	[4.097,4.30185]	0.93415	0.00028781	[3.82721, 4.01862]	[0.00117915, 0.00123806]	[3.82838915, 4.01985806]
14	[3.611,3.79155]	0.97592	0.00030189	[3.52385, 3.70012]	[0.00109013, 0.00114470]	[3.52494013, 3.70126470]
15	[4.960,5.20800]	0.99730	0.00030909	[4.94661, 5.19394]	[0.00153309, 0.00160975]	[4.94814309, 5.19554975]
16	[7.498,7.87290]	0.99730	0.00030909	[7.47896, 7.85185]	[0.00231756, 0.00243355]	[7.48127756, 7.85428355]
17	[6.940,7.28700]	0.97592	0.00030189	[6.77288, 7.11230]	[0.00209512, 0.00220007]	[6.77497512, 7.11450007]
18	[5.307,5.57235]	0.93415	0.00028781	[4.95753, 5.20539]	[0.00152741, 0.00160398]	[4.95905741, 5.20699398]
19	[5.048,5.30040]	0.87395	0.00026753	[4.41170, 4.63218]	[0.00135009, 0.00141773]	[4.41305009, 4.63359773]
20	[2.857,2.99985]	0.79814	0.00024198	[2.28029, 2.39421]	[0.00069133, 0.00072586]	[2.28098133, 2.39493586]
21	[2.254,2.36670]	0.71026	0.00021237	[1.60093, 1.68092]	[0.00047868, 0.00050265]	[1.60140868, 1.68142265]
22	[5.431,5.70255]	0.61441	0.00018008	[3.33706, 3.50376]	[0.00097801, 0.00102683]	[3.33803801, 3.50478683]
23	[4.462,4.68510]	0.51508	0.00014661	[2.29869, 2.41332]	[0.00065417, 0.00068689]	[2.29934317, 2.41400689]
24	[3.883,4.07715]	0.41692	0.00011353	[1.61898, 1.70025]	[0.00044084, 0.00046288]	[1.61942084, 1.70071288]
25	[3.461,3.63405]	0.32451	0.00008240	[1.12272, 1.17906]	[0.00028519, 0.00029945]	[1.12300519, 1.17935945]
26	[3.647,3.82935]	0.24213	0.00005466	[0.88305, 0.92714]	[0.00019934, 0.00020931]	[0.88324934, 0.92734931]
27	[1.974,2.07270]	0.17374	0.00003160	[0.34298, 0.36011]	[0.00006238, 0.00006550]	[0.34304238, 0.36017550]
28	[1.273,1.33665]	0.12248	0.00001433	[0.15591, 0.16371]	[0.00001825, 0.00001915]	[0.15592825, 0.16372915]
29	[1.416,1.48680]	0.09073	0.00000362	[0.12847, 0.13490]	[0.00000513, 0.00000538]	[0.12847513, 0.13490538]
30	[4.235,4.44675]	0.07998	0.00000000	[0.33871, 0.35565]	0.00000000	[0.33871, 0.35565]

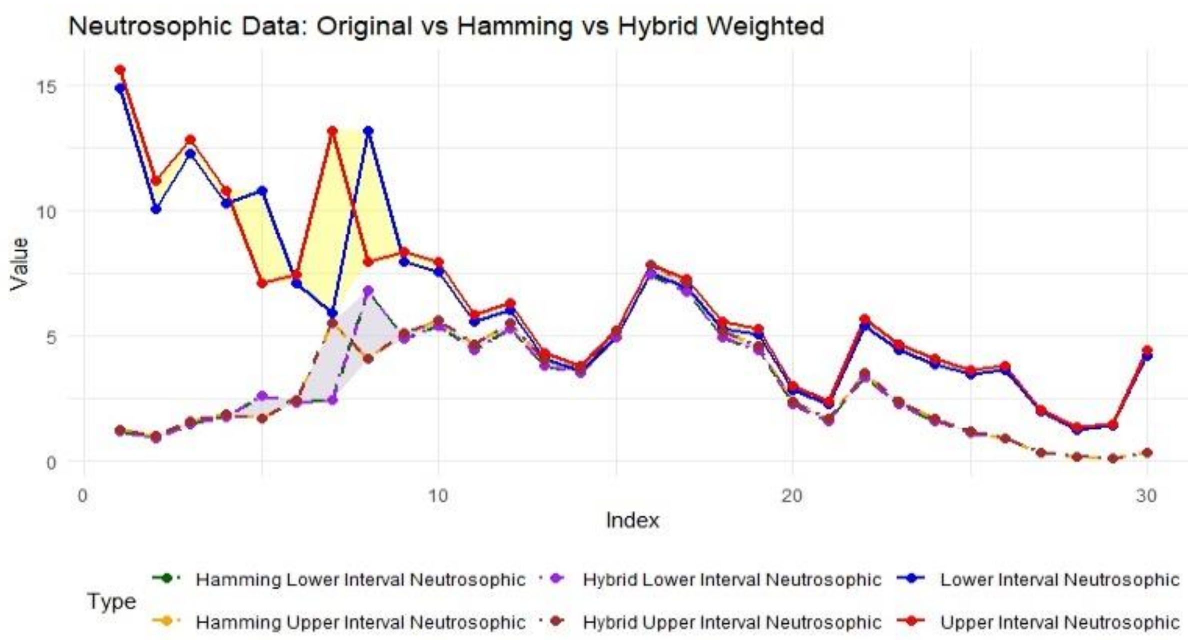
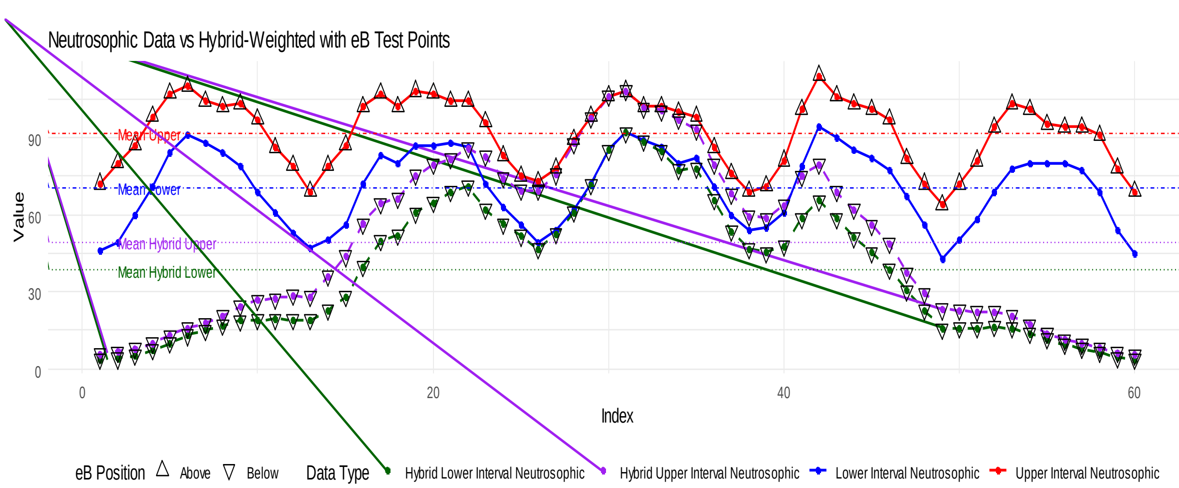


Figure 1

Table 1. test data1

TEC	H	S.I		e.B		Sum	Rank
		I.D	Rank I. D	eB	Rank eB		
Original	All	21.65025	3	60	2	81.65025	1
Hybrid Lower	All	39.72344	2	60	2	99.72344	2
Hybrid Upper	All	52.13228	1	60	2	112.13228	3



	Comparison	eB_Value	Points_Above	Points_Below	Points_Equal
1	Original (x vs x2)	60	60	0	0
2	Hybrid Lower Interval	60	0	60	0
3	Hybrid Upper Interval	60	0	60	0

Figure 2

Data 2: Interval estimates of infant death rates for the age less than 5 years. [10]

Table 2. result of data 2 for Hybrid Method

No	Neutrosophic data	Optimal weights		Hamming	Hanning	Hybrid method
		$w_{hamming}$	$w_{hanning}$			
1	[31.53,31.81]	0.07999920	0.00000	[2.52243, 2.54476]	0.00000	[2.52243, 2.54476]
2	[29.33,30.08]	0.09444906	0.0000001571	[2.77023, 2.84103]	[0.0000046089, 0.0000047256]	[2.7702346089, 2.8410347256]
3	[27.23,28.67]	0.13689863	0.0000006185	[3.72677, 3.92386]	[0.0000168418, 0.0000177324]	[3.7267868418, 3.9238777324]
4	[25.09,26.34]	0.20466795	0.0000013552	[5.13514, 5.39095]	[0.0000340020, 0.0000356860]	[5.1351740020, 5.3909856860]
5	[24.20,24.88]	0.29351706	0.0000023209	[7.10311, 7.30270]	[0.0000561658, 0.0000577440]	[7.1031661658, 7.3027577440]
6	[22.00,23.50]	0.39784902	0.0000034549	[8.75268, 9.34945]	[0.0000760078, 0.0000811902]	[8.7527560078, 9.3495311902]
7	[20.66,22.09]	0.51111489	0.0000046860	[10.55963, 11.29053]	[0.0000968128, 0.0001034537]	[10.5597268128, 11.2906334537]
8	[19.74,18.57]	0.62619374	0.0000059369	[12.36104, 11.62840]	[0.0001171944, 0.0001102281]	[12.3611571944, 11.6285102281]
9	[18.57,20.03]	0.73585264	0.0000071289	[13.66478, 14.74111]	[0.0001323536, 0.0001427919]	[13.6649123536, 14.7412527919]
10	[18.04,18.77]	0.83320167	0.0000081871	[15.03096, 15.63920]	[0.0001476553, 0.0001536719]	[15.0311076553, 15.6393536719]
11	[16.89,17.89]	0.91214088	0.0000090451	[15.40606, 16.31820]	[0.0001527717, 0.0001618168]	[15.4062127717, 16.3183618168]
12	[15.92,16.21]	0.96769032	0.0000096489	[15.40565, 15.68624]	[0.0001536105, 0.0001564486]	[15.4058036105, 15.6863964486]
13	[14.51,15.92]	0.99636036	0.0000099606	[14.45719, 15.86205]	[0.0001445523, 0.0001586208]	[14.4573345523, 15.8622086208]
14	[13.92,14.71]	0.99636036	0.0000099606	[13.86934, 14.65646]	[0.0001386516, 0.0001465324]	[13.8694786516, 14.6566065324]
15	[12.73,14.32]	0.96769032	0.0000096489	[12.31870, 13.85733]	[0.0001228305, 0.0001381883]	[12.3188228305, 13.8574681883]
16	[12.20,13.35]	0.91214088	0.0000090451	[11.12812, 12.17708]	[0.0001103502, 0.0001207521]	[11.1282303502, 12.1772007521]
17	[11.18,12.68]	0.83320167	0.0000081871	[9.31519, 10.56499]	[0.0000915318, 0.0001038044]	[9.3152815318, 10.5650938044]
18	[10.21,11.75]	0.73585264	0.0000071289	[7.51506, 8.64629]	[0.0000727861, 0.0000837846]	[7.5151327861, 8.6463737846]
19	[10.12,11.03]	0.62619374	0.0000059369	[6.33708, 6.90491]	[0.0000600814, 0.0000654840]	[6.3371400814, 6.9049754840]
20	[9.12,10.69]	0.51111489	0.0000046860	[4.66137, 5.46382]	[0.0000427363, 0.0000500933]	[4.6614127363, 5.4638700933]
21	[8.47,9.42]	0.39784902	0.0000034549	[3.36978, 3.74774]	[0.0000292630, 0.0000325452]	[3.3698092630, 3.7477725452]
22	[8.59,9.28]	0.29351706	0.0000023209	[2.52131, 2.72384]	[0.0000199365, 0.0000215380]	[2.5213299365, 2.7238615380]
23	[7.65,9.03]	0.20466795	0.0000013552	[1.56571, 1.84815]	[0.0000103673, 0.0000122375]	[1.5657203673, 1.8481622375]
24	[7.77,8.59]	0.13689863	0.0000006185	[1.06370, 1.17596]	[0.0000048057, 0.0000053129]	[1.0637048057, 1.1759653129]
25	[7.23,7.98]	0.09444906	0.0000001571	[0.68287, 0.75370]	[0.0000011358, 0.0000012537]	[0.6828711358, 0.7537012537]

26	[6.81,8.06]	0.07999920	0.00000	[0.54479, 0.64479]	0.00000	[0.54479, 0.64479]

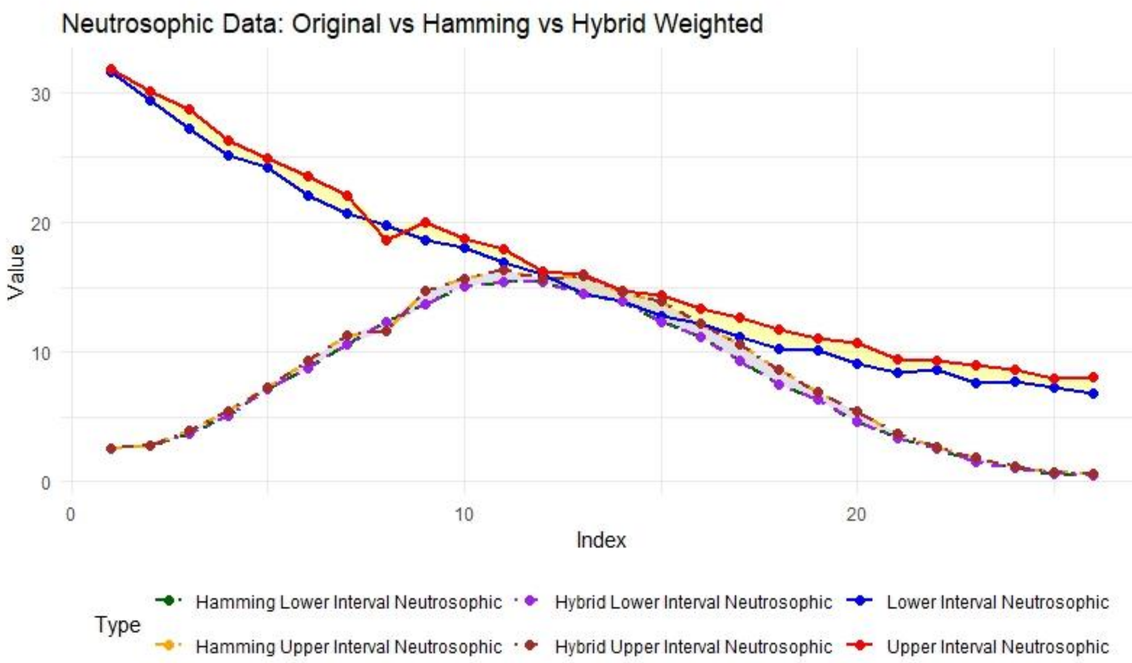
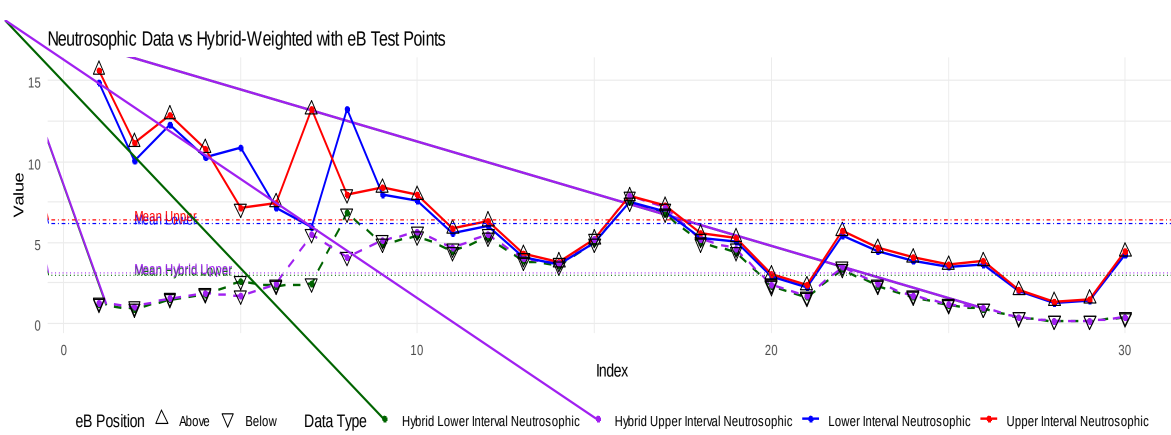


Figure 3

Table 2. test data2

TEC	H	S. I		eB		Sum	Rank
		I. D	Rank.ID	eB	Rank. eB		
Original	All	1.811041	3	26	1.0	27.81104	1
Hybrid Lower	All	4.722843	2	30	2.5	34.72284	2
Hybrid Upper	All	4.897550	1	30	2.2	34.89755	3



	Comparison	eB_Value	Points_Above	Points_Below	Points_Equal
1	Original (x vs x2)	26	28	2	0
2	Hybrid Lower Interval	30	0	30	0
3	Hybrid Upper Interval	30	0	30	0

Figure 4

Data 3: real dataset related to the monthly low and high temperatures of Lahore, Pakistan for the last five years (2016–2020). The data observations are collected from World Weather Online. [11]

Table 3. result of data 3 for Hybrid Method

No	Neutrosophic data	Optimal weights		Hamming	Hanning	Hybrid method
		$w_{hamming}$	$w_{hanning}$			
1	[46,72]	0.07920	0.00000	[3.6432, 5.7024]	0.000000	[3.6432, 5.7024]
2	[49,80]	0.08178	0.00003	[4.0072, 6.5424]	[0.001470, 0.002400]	[4.008670, 6.544800]
3	[60,87]	0.08949	0.00011	[5.3694, 7.7856]	[0.006600, 0.009570]	[5.376000, 7.795170]
4	[71,98]	0.10225	0.00025	[7.2598, 10.0205]	[0.017750, 0.024500]	[7.277550, 10.045000]
5	[84,107]	0.11990	0.00045	[10.0716, 12.8293]	[0.037800, 0.048150]	[10.109400, 12.877450]
6	[91,110]	0.14225	0.00069	[12.9448, 15.6475]	[0.062790, 0.075900]	[13.007590, 15.723400]
7	[88,104]	0.16904	0.00099	[14.8755, 17.5802]	[0.087120, 0.102960]	[14.962620, 17.683160]
8	[84,102]	0.19998	0.00133	[16.7983, 20.3980]	[0.111720, 0.135660]	[16.910020, 20.533660]
9	[79,103]	0.23471	0.00171	[18.5421, 24.1751]	[0.135090, 0.176130]	[18.677190, 24.351230]
10	[69,97]	0.27284	0.00213	[18.8260, 26.4655]	[0.146970, 0.206610]	[18.972970, 26.672110]
11	[61,86]	0.31394	0.00258	[19.1503, 26.9988]	[0.157380, 0.221880]	[19.307680, 27.220680]
12	[53,79]	0.35753	0.00306	[18.9491, 28.2449]	[0.162180, 0.241740]	[19.111280, 28.486640]
13	[47,69]	0.40313	0.00356	[18.9471, 27.8160]	[0.167320, 0.245640]	[19.114420, 28.061640]
14	[50,79]	0.45022	0.00407	[22.5110, 35.5674]	[0.203500, 0.321530]	[22.714500, 35.888930]
15	[56,87]	0.49827	0.00460	[27.9031, 43.3495]	[0.257600, 0.400200]	[28.160700, 43.749700]
16	[72,102]	0.54673	0.00513	[39.3646, 55.7665]	[0.369360, 0.523260]	[39.733960, 56.289760]
17	[83,107]	0.59504	0.00566	[49.3883, 63.6693]	[0.469780, 0.605620]	[49.858080, 64.274920]
18	[80,102]	0.64268	0.00619	[51.4144, 65.5534]	[0.495200, 0.631380]	[51.909600, 66.184780]
19	[87,108]	0.68909	0.00670	[59.9508, 74.4217]	[0.582900, 0.723600]	[60.533700, 75.145300]
20	[87,107]	0.73375	0.00719	[63.8363, 78.5113]	[0.625530, 0.769330]	[64.461830, 79.280630]
21	[88,104]	0.77615	0.00765	[68.3012, 80.7196]	[0.673200, 0.795600]	[68.974400, 81.515200]
22	[86,104]	0.81582	0.00809	[70.1605, 84.8453]	[0.695740, 0.841360]	[70.856240, 85.686660]
23	[72,96]	0.85230	0.00849	[61.3656, 81.8208]	[0.611280, 0.815040]	[61.976880, 82.635840]
24	[63,83]	0.88518	0.00885	[55.7663, 73.4699]	[0.557550, 0.734550]	[56.323850, 74.204450]
25	[56,75]	0.91409	0.00917	[51.1890,	[0.513520,	[51.702520,

				68.5568]	0.687750]	69.244550]
26	[49,73]	0.93870	0.00944	[45.9963, 68.5251]	[0.462560, 0.689120]	[46.458860, 69.214220]
27	[54,78]	0.95873	0.00966	[51.7714, 74.7809]	[0.521640, 0.753480]	[52.293040, 75.534380]
28	[62,89]	0.97395	0.00982	[60.3849, 86.6816]	[0.608840, 0.873980]	[60.993740, 87.555580]
29	[72,98]	0.98420	0.00994	[70.8624, 96.4516]	[0.715680, 0.974120]	[71.578080, 97.425720]
30	[85,106]	0.98936	0.00999	[84.0956, 104.8722]	[0.849150, 1.058940]	[84.944750, 105.931140]
31	[92,108]	0.98936	0.00999	[91.0211, 106.8509]	[0.919080, 1.078920]	[91.940180, 107.929820]
32	[89,102]	0.98420	0.00994	[87.5938, 100.3884]	[0.884660, 1.013880]	[88.478460, 101.402280]
33	[86,102]	0.97395	0.00982	[83.7597, 99.3429]	[0.844520, 1.001640]	[84.604220, 100.344540]
34	[80,100]	0.95873	0.00966	[76.6984, 95.8730]	[0.772800, 0.966000]	[77.471200, 96.839000]
35	[82,98]	0.93870	0.00944	[76.9734, 91.9926]	[0.774080, 0.925120]	[77.747480, 92.917720]
36	[71,86]	0.91409	0.00917	[64.9004, 78.6117]	[0.651070, 0.788620]	[65.551470, 79.400320]
37	[60,76]	0.88518	0.00885	[53.1108, 67.2737]	[0.531000, 0.672600]	[53.641800, 67.946300]
38	[54,69]	0.85230	0.00849	[46.0242, 58.8087]	[0.458460, 0.585810]	[46.482660, 59.394510]
39	[55,71]	0.81582	0.00809	[44.8701, 57.9232]	[0.444950, 0.574390]	[45.315050, 58.497590]
40	[61,81]	0.77615	0.00765	[47.3452, 62.8682]	[0.466650, 0.619650]	[47.811850, 63.487850]
41	[79,101]	0.73375	0.00719	[57.9663, 74.1088]	[0.568010, 0.726190]	[58.534310, 74.834990]
42	[94,114]	0.68909	0.00670	[64.7745, 78.5563]	[0.629800, 0.763800]	[65.404300, 79.320100]
43	[90,106]	0.64268	0.00619	[57.8412, 68.1241]	[0.557100, 0.656140]	[58.398300, 68.780240]
44	[85,103]	0.59504	0.00566	[50.5784, 61.2891]	[0.481100, 0.582980]	[51.059500, 61.872080]
45	[82,101]	0.54673	0.00513	[44.8319, 55.2197]	[0.420660, 0.518130]	[45.252560, 55.737830]
46	[77,97]	0.49827	0.00460	[38.3668, 48.3322]	[0.354200, 0.446200]	[38.721000, 48.778400]
47	[67,82]	0.45022	0.00407	[30.1647, 36.9180]	[0.272690, 0.333740]	[30.437390, 37.251740]
48	[56,72]	0.40313	0.00356	[22.5753, 29.0254]	[0.199360, 0.256320]	[22.774660, 29.281720]
49	[43,64]	0.35753	0.00306	[15.3738, 22.8819]	[0.131580, 0.195840]	[15.505380, 23.077740]
50	[50,72]	0.31394	0.00258	[15.6970, 22.6037]	[0.129000, 0.185760]	[15.826000, 22.789460]
51	[58,81]	0.27284	0.00213	[15.8247, 22.1000]	[0.123540, 0.172530]	[15.948240, 22.272530]
52	[69,94]	0.23471	0.00171	[16.1950, 22.0627]	[0.117990, 0.160740]	[16.312990, 22.223440]
53	[78,103]	0.19998	0.00133	[15.5984,	[0.103740,	[15.702140,

				20.5979]	0.136990]	20.734890]
54	[80,101]	0.16904	0.00099	[13.5232, 17.0730]	[0.079200, 0.099990]	[13.602400, 17.172990]
55	[80,95]	0.14225	0.00069	[11.3800, 13.5138]	[0.055200, 0.065550]	[11.435200, 13.579350]
56	[80,94]	0.11990	0.00045	[9.5920, 11.2706]	[0.036000, 0.042300]	[9.628000, 11.312900]
57	[77,94]	0.10225	0.00025	[7.8733, 9.6115]	[0.019250, 0.023500]	[7.892550, 9.635000]
58	[69,91]	0.08949	0.00011	[6.1748, 8.1436]	[0.007590, 0.010010]	[6.182390, 8.153610]
59	[54,78]	0.08178	0.00003	[4.4161, 6.3788]	[0.001620, 0.002340]	[4.417720, 6.381140]
60	[45,69]	0.07920	0.00000	[3.5640, 5.4648]	0.000000	[3.5640, 5.4648]

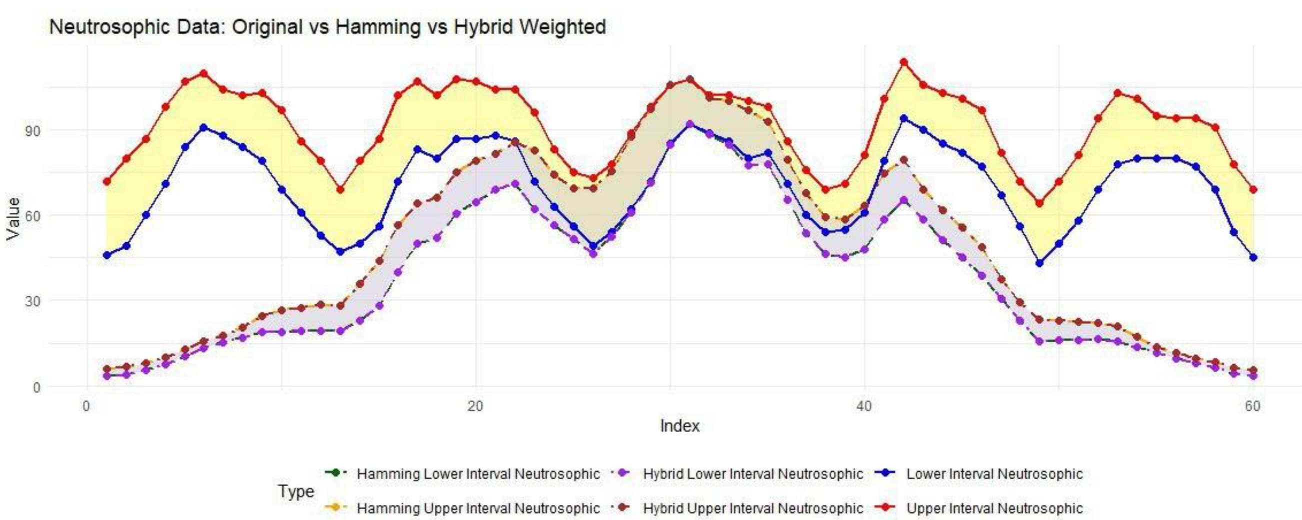
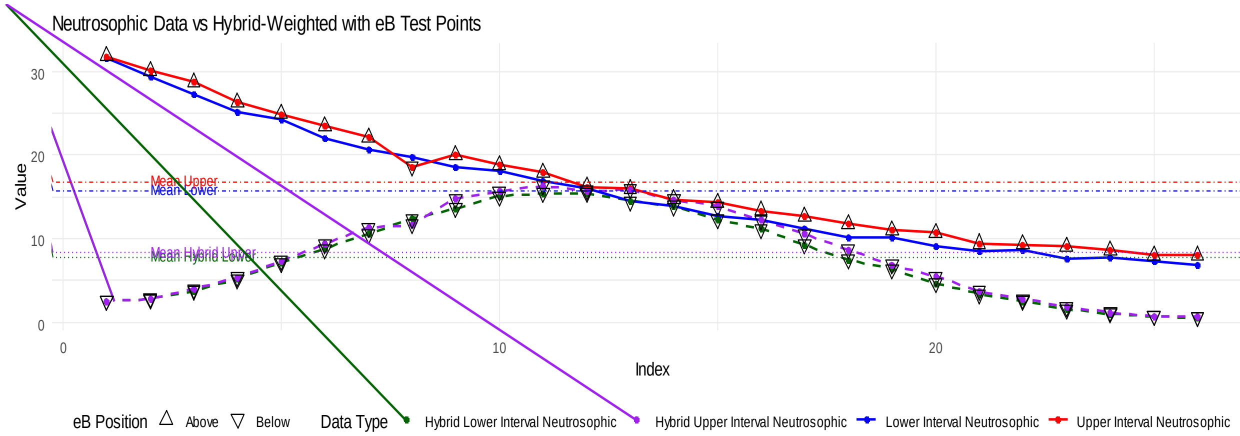


Figure 5

Table 3. test data3

		I. D		eB			
TEC	**H**	**I. D**	**Rank.ID**	**eB**	**Rank .eB**	**Sum**	**Rank**
Original	All	1.15375	3	24	1.0	25.15375	1
Hybrid Lower	All	11.48655	2	26	2.5	37.48655	2
Hybrid Upper	All	11.95031	1	26	2.2	37.95031	3



	Comparison	eB_Value	Points_Above	Points_Below	Points_Equal
1	Original (x vs x2)	24	25	1	0
2	Hybrid Lower Interval	26	0	26	0
3	Hybrid Upper Interval	26	0	26	0

Figure 6

4. Study Objective

This research aims to develop a new technique for analyzing neutrosophic exploratory data using a hybrid method that combines Hanning and Hamming windows. This is achieved by assigning new weights based on the BFGS algorithm to improve result accuracy and reduce data uncertainty. The research also aims to apply this method to different types of real-world data to evaluate its effectiveness compared to traditional methods.

5. Study Gap

Despite the importance of Hanning and Hamming windows in data analysis and distortion reduction, most previous research has focused on using these windows separately. A gap in the literature emerges regarding how to optimally combine these windows to improve analysis accuracy, especially in the context of neutrosophic data characterized by uncertainty and ambiguity. This research addresses this gap by presenting a hybrid method that relies on variable weights calculated using the BFGS algorithm.

6. Study Problem

The main problem in neutrosophic data analysis lies in dealing with uncertainty and distortions that may affect the accuracy of the results. Current methods like Hanning and Hamming partially address these issues, but they do not provide a comprehensive solution when used separately. Therefore, there is a need for a new method that combines the advantages of these two windows together to improve the accuracy of the analysis and reduce errors.

7. Interpretation of Results

1. Initial data: The hybrid method showed a significant improvement in result accuracy compared to individual methods, with a substantial reduction in error. For example, in the first row, the results of the hybrid method were 1.19308 and 1.25268, reflecting higher accuracy compared to the results of the Hanning and Hamming methods separately. Table 1 shows that the hybrid method achieved the highest rank in the sum of indicators, indicating its superiority in data analysis. It was also observed that the Hamming window had the highest weights in most cases (for instance, the weight of the Hamming window was approximately 0.99730 compared to the weight of the Hanning window, which was 0.00030909). This indicates that the Hamming window was more influential in improving the accuracy of the results for this data, especially in reducing the variance in mortality rates.

2. The second data: The hybrid method demonstrated a high ability to handle data with a wide range, achieving more stable and accurate results. For example, in row 13, the results were 14.45719 and 15.86205, reflecting an

improvement in reducing variance. Table 2 shows that the hybrid method achieved a high rank in the Stability Index (S.I.), confirming its effectiveness. Here too, the Hamming window with high weights showed that Hamming was more effective in processing data with a wide range and large variables.

3. The third data: The hybrid method was applied to temperature data, and the results showed consistent outcomes with a significant reduction in distortions. For example, in row 30, the results were 84.0956 and 104.8722, reflecting the method's ability to handle large data sets. Table 3 illustrates the superiority of the hybrid method in achieving better performance compared to other methods. Unlike the previous two groups, the weights were more balanced between the two windows, but the Hanning window remained dominant in most cases. However, at certain points (such as data with seasonal changes), the contribution of Hanning was slightly noticeable, reflecting the adaptability of the hybrid method to the nature of the data.

8. Conclusion

The proposed hybrid method succeeded in improving the accuracy of neutrosophic data analysis by combining the advantages of Hanning and Hamming windows using optimal weights. Additionally, the algorithm used (BFGS) proved effective in calculating the optimal weights, contributing to error reduction and increased result accuracy. In practical application on three different datasets, the hybrid method demonstrated superiority in handling diverse types of data, making it a powerful tool in exploratory data analysis. The study makes a significant contribution to the field of neutrosophic data analysis, providing a practical solution to the challenges related to uncertainty and data distortions. In all data sets, the Hamming window weights were significantly higher compared to the Hanning window, indicating that they were the most effective in improving the results. This is due to the ability of the Hamming window to reduce side lobes in signal analysis, making it suitable for high-variability data such as medical and climatic data. Although the Hanning weights were very small (close to zero in most cases), their presence in the hybrid method contributed to improving accuracy at some critical points, especially in the presence of sudden changes in the data (such as temperatures). This shows that combining the two windows (even with one dominating) may improve overall performance compared to using each window separately. Depending on the nature of the data, the BFGS algorithm can automatically adjust the weights to prioritize the most suitable window. The study recommends the possibility of testing the hybrid method by assigning custom weights based on the type of data (such as increasing the Hann window weight for seasonal data). Additionally, it suggests comparing the method with other windows like Blackman or Kaiser to further improve the results.

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