A job-sequencing problem using modified score function in PNN environment

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Abstract: Pentagonal neutrosophic number (PNN) is an extension of general established triangular and trapezoidal neutrosophic number. In this article, the structural form of PNN has been applied on operational research-based job-sequence problems. Here, we mainly focused on the modified score and accuracy function of PNN and its application in different perspectives. Further, a job-sequencing model has been developed in PNN environment and resolved it using the modified score function and lastly, compared it with established score function of PNN. This novel thought will help the researchers to do further expansion of PNN in upcoming days.

Keywords: pentagonal neutrosophic number; PNN; score and accuracy function; job-sequencing problem.

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1 Introduction

The conception of vagueness and dilemma of human thinking plays a remarkable role in this current century. Professor Zadeh (1965) first manifested the concept of fuzzy set (FS) in 1965 and since then, it was widely applied in various fields of mathematics, engineering and medical sciences. Further, Atanassov (1986) extended the idea of FS and established the logical significance of intuitionistic fuzzy set (IFS) in which the idea of both membership and non-membership functions are considered. Moreover, researchers developed trapezoidal (Abbasbandy and Hajjari, 2009), pentagonal (Chakraborty et al., 2019a), hexagonal (Chakraborty et al., 2020a), heptagonal (Maity et al., 2019) FS in this current decade and applied these on several application based problems. Further, Liu and Yuan (2007) manifested triangular and Ye (2014) describes the idea of trapezoidal IFS which are the logical combination of IFS and triangular, trapezoidal F.S. Several excellent works has been published in this FS and IFS arena till now. After that, Smarandache (1998) established the perception of neutrosophic set (NS) in 1998 having three special fundamental components namely,

1 truth
2 hesitant
3 falsity.

Invention of NS is nothing but the extension of IFS and it can deal with any kind of realistic problem in a proper logical way. Since then, numerous of articles are published in this domain and the developments are going on rapidly. Further, Wang et al. (2010) manifested the idea of single typed NS, Kumar et al. (2018) focused on neutrosophic shortest path (SP), Broumi et al. (2019) analysed bellman shaped SP problem, Chakraborty et al. (2018, 2019b) germinated the thought of triangular and trapezoidal NS and it is categorisation according to the dependency, Bosc and Pivert (2013) promoted the notion of bipolarity, Abdel-Basset et al. (2019) developed the perception of type-2 NS, Deli et al. (2015) introduced the concept of bipolar NS, Broumi et al. (2016) established bipolar neutrosophic graph theory concept, Ali and Smarandache (2016) ignited the idea of the complex NS, Nabeeh et al. (2019) characterised neutrosophic AHP skill, Mullai and Broumi (2018) focused on minimum spanning tree problem in NS arena, Chakraborty et al. (2020b) and Chakraborty (2019) introduced cylindrical neutrosophic logic, Pal and Chakraborty (2020) established EOQ-based neutrosophic model, Haque et al. (2020) proposed generalised spherical set concept etc. Instead of these developments in neutrosophic world, recently in 2019, Chakraborty et al. (2019c) focused on the structural developments of NS and invented the conception of pentagonal neutrosophic number (PNN). Later, Chakraborty et al. (2019d) established the concept of crispification for PNN namely de-neutrosophic skill and applied it in minimal spanning tree problem. Also, Chakraborty et al. (2020c) manifested aggregation operator on PNN and developed MCGDM problem and further applied the established score function into networking field (Chakraborty, 2020a, 2020b). Also, in this current era, many of the researchers developed several articles in decision making problems like Wang et al. (2016) proposed linguistic MCGDM problem in engineering field, Jiang and Li (1996) ignited learning model using defuzzification skill, Mahata et al. (2019) prepared mathematical diabetes fuzzy model, Biswas et al. (2016) developed TOPSIS technique related MCGDM problem, Huang et al. (2017) manifested VIKOR-based MCGDM, Stanujkic et al. (2017) presents MULTIMOORA skill on MCDM, Chakraborty et al. (2019e) established bipolar neutrosophy logic based MCGDM PROBLEM etc. Recently, numerous articles are published in netro-logic based operation research problem like Hariri and El-Ata (1997) germinated GP approach to solve inventory model varying order cost, Jung and Klein (2001) manifested comparative study between the total cost minimisation and the profit maximisation model, Mandal et al. (2006) introduced inventory model of declined items utilising GP method, Leung (2007) manifested an EPQ model having flexible and imperfect production method using GP approach, Wakeel et al. (2008) proposed multi-product, multi-vendors inventory models under linear and non-linear constraints, Roy and Das (2015) resolved multi objective production planning problem in neutro-logic arena, Banerjee and Pramanik (2018) formulated linear GP problem in neutrosophic atmosphere, Pramanik and Banerjee (2018) invented three new neutrosophic GP model to explain neutrosophic multi objective programming problem.

In this paper, the established PNN is applied in a job-sequencing based operation research related problem. Moreover, a new score function is proposed here in PNN environment and utilised it to do the application oriented problems. Here, we used the idea of score function in job-sequencing problems and lastly compared it with the result of established score function. This novel score function will help the researchers in future studies in PNN arena.

1.1 Motivation

Several works has been already published in PNN arena till now and the need of crispification is also described in different articles. Now, question will arise how can we modify the crispification technique in PNN arena and generate better solution rather than the established method? How can we implement it in an operation research problem? From this aspect we actually try to extend this research article.

1.2 Novelties

Though few works has been published in PNN arena but still lots of modification can be done here. In this article, we mainly focused on this following listed points.

1 Proposed modified logical score and accuracy function.

2 Application of PNN in job-sequencing problem.

3 Compared the results with previous established score function.

2 Preliminaries

Definition: fuzzy set (F.S): (Zadeh, 1965) $\breve{L}$ is identified as a fuzzy set, for the pair $(x, \mu_{\breve{L}}(x))$ it can be written as $\breve{L} = \{(x, \mu_{\breve{L}}(x)) : x \in X, \mu_{\breve{L}}(x) \in [0, 1]\}$.

Definition: Intuitionistic fuzzy set (IFS): (Atanassov, 1986) $\tilde{S}_F$ is identified as an intuitionistic set if $S_F = \{\langle x; [\varphi(x), \omega(x)]\rangle \vdots x \in X = universal\ set\}$, where $\varphi(x)$, $\omega(x)$ $\in$ [0, 1] is termed as membership function, is termed as non-membership function.

$\varphi(x)$, $\omega(x)$ exhibits the following relation $0 \le \varphi(x) + \omega(x) \le 1$.

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Definition: Single-valued neutrosophic set (SNS): (Wang et al., 2010) A set $\widetilde{NEU}_M$ in the Definition 2.3 is called as SNS $(S\widetilde{NEU}_M)$ if x is a single-valued independent variable.

$$-0 \le Sup\left\{\theta_{\widetilde{NEU}_M}(x)\right\} + Sup\left\{\varphi_{\widetilde{NEU}_M}(x)\right\} + Sup\left\{\sigma_{\widetilde{NEU}_M}(x)\right\} \le 3$$

$\widetilde{SNEUA} = \{< x : [\theta_{S\widetilde{NEU}}(x), \varphi_{S\widetilde{NEU}}(x), \sigma_{S\widetilde{NEU}}(x)] >: x \in X\}$, $\theta_{S\widetilde{NEU}}(x), \varphi_{S\widetilde{NEU}}(x), \sigma_{S\widetilde{NEU}}(x)$ signified the notion of correct, indefinite and incorrect memberships function respectively.

Definition: Single valued pentagonal neutrosophic number (SPNN) (Chakraborty et al., 2019c).

A SPNN $(\hat{M})$ is defined as ($SPNEU$ = ⟨[(m^1, n^1, o^1, p^1, q^1):μ], [(m^2, n^2, o^2, p^2, q^2): θ], [(m^3, n^3, o^3, p^3, q^3): η]⟩)ˇ, where $\mu, \theta, \eta \in [0, 1]$. The truth membership function $\mu_{S\widetilde{NEU}}$: $R \rightarrow [0, \mu]$, the hesitant membership function $\theta_{S\widetilde{NEU}}$: $R \rightarrow [\theta, 1]$ and the false membership function are $\eta_{S\widetilde{NEU}}$: $R \rightarrow [\eta, 1]$ given as:

$$\mu_{S\widetilde{PNEU}}(x) = \begin{cases} \mu_{\widetilde{Ssl1}}(x) & m^1 \le x < n^1 \\ \mu_{\widetilde{Ssl2}}(x) & n^1 \le x < o^1 \\ \mu & x = o^1 \\ \mu_{\widetilde{Ssr2}}(x) & o^1 \le x < p^1 \\ \mu_{\widetilde{Ssr1}}(x) & p^1 \le x < q^1 \\ 0 & \text{otherwise} \end{cases}; \quad \theta_{S\widetilde{PNEU}}(x) = \begin{cases} \theta_{\widetilde{Ssl1}}(x) & m^2 \le x < n^2 \\ \theta_{\widetilde{Ssl2}}(x) & n^2 \le x < o^2 \\ \vartheta & x = o^2 \\ \theta_{\widetilde{Ssr2}}(x) & o^2 \le x < p^2 \\ \theta_{\widetilde{Ssr1}}(x) & p^2 \le x < q^2 \\ 1 & \text{otherwise} \end{cases}$$

$$\eta_{S\widetilde{PNEU}}(x) = \begin{cases} \eta_{\widetilde{Ssl1}}(x) & m^3 \le x < n^3 \\ \eta_{\widetilde{Ssl2}}(x) & n^3 \le x < o^3 \\ \vartheta & x = o^3 \\ \eta_{\widetilde{Ssr2}}(x) & o^3 \le x < p^3 \\ \eta_{\widetilde{Ssr1}}(x) & p^3 \le x < q^3 \\ 1 & \text{otherwise} \end{cases}$$

3 Modified score and accuracy function

The primary application of score function is to drag the judgment of conversion of PNN to crisp number. Previously, Chakraborty et al. (2019c) proposed a score function in PNN environment for crispification. But, here we modify it according to the following logic. Here, we consider the beneficiary membership value of PNN with respect to hesitation function and it is described as $(1 - \pi^2 - \sigma^2)$ also, the beneficiary membership value of PNN with respect to falsity function is described as $(1 - \pi^2 - \rho^2)$. Now, we take the mean of these two components that is $\left\{\frac{(1-\pi^2-\sigma^2)+(1-\pi^2-\rho^2)}{2}\right\}$. Also, the mean of the PNN components is $\frac{1}{5}(R_1 + R_2 + R_3 + R_4 + R_5)$. Thus, for a PNN $\tilde{R}_{Pen}$ = (R_1, R_2, R_3, R_4, R_5; π, σ, ρ, score function is scaled as

$$\widetilde{SC}_{Pen} = \frac{1}{10}\left(R_1 + R_2 + R_3 + R_4 + R_5\right) \times \left\{(1-\pi^2-\sigma^2)+(1-\pi^2-\rho^2)\right\}$$

Here, $\widetilde{SC_{Pen}} \in \widetilde{RC_{Pen}} \in R$.

Relationship between any two PNN

Let us consider any two pentagonal neutrosophic fuzzy number defined as follows

$$R_{Pen1} = \left(\pi_{Pen1}, \sigma_{Pen1}, \rho_{Pen1}\right), R_{Pen2} = \left(\pi_{Pen2}, \sigma_{Pen2}, \rho_{Pen2}\right)$$

1 $SC_{Pen1} > SC_{Pen2}$, $R_{Pen1} > R_{Pen2}$

2 $SC_{Pen1} < SC_{Pen2}$, $R_{Pen1} < R_{Pen2}$

3 $SC_{Pen1} = SC_{Pen2}$, $R_{Pen1} = R_{Pen2}$.

Then

$$AC_{Pen1} > AC_{Pen2}, R_{Pen1} > R_{Pen2}$$

$$AC_{Pen1} < AC_{Pen2}, R_{Pen1} < R_{Pen2}$$

$$AC_{Pen1} = AC_{Pen2}, R_{Pen1} = R_{Pen2}$$

Table 1 Numerical examples

Pentagonal neutrosophic number (R_{Pen})	*Score value (SC_{Pen})*	*Ordering*
R_{Pen1} = <(0.2,0.3,0.4,0.5,0.6; 0.4,0.3,0.6)>	0.246	$R_{Pen4} > R_{Pen2} > R_{Pen2} > R_{Pen3}$
R_{Pen2} = <(0.30,0.35,0.45,0.55,0.6; 0.6,0.4,0.5)>	0.196	
R_{Pen3} = <(0.1,0.2,0.25,0.3,0.45; 0.6,0.7,0.5)>	0.071	
R_{Pen4} = <(0.6,0.7,0.85,0.9,1; 0.3,0.5,0.6)>	0.490	

4 Application of PNN in job-sequencing problem

Sequencing problems are responsible for a suitable choice of a sequence of jobs undertaken on a finite number of service amenities in some definite technological arrangements so as to optimize some effectiveness measure such as total elapsed time or general cost etc. There steps the complexity in solving a sequencing problem if there is an amount of uncertainty but the problem can be resolve quiet simply using less attempts by applying the thought of vagueness and its corresponding crispified value. In this ground, we have taken a sequencing problem in which there is an operation of three dissimilar machines and with the occurrence of a spectrum of dissimilar jobs to be contented. To revolve the system into neutrosophic in nature, we consider the PNN in the feature of time in the database table. Let us consider, there are '*m*' jobs processing on three machines M_1, M_2, M_3 one by one. The optimal sequence can be computed by converting the problem into two-machines. To do this we need maintain some of the following steps:

Step 1 Convert each of the PNN into general crisp value using score function.

Step 2 Find the minimum processing time for the jobs on first and third machine and maximum for the second machine, then check the relation Min(1st) ≥ Max(2nd) or Min(3rd) ≥ Max(2nd).

Step 3 If both the conditions failed then this method cannot be applicable.

Step 4 Otherwise, if any of the relation holds then we define two machines R and S as

$R_i = M_{1i} + M_{2i}$ and $S_i = M_{2i} + M_{3i}$

Step 5 After the conversion we can apply the job-sequencing algorithm for two machines.

Illustrative example: here, we construct a problem having five distinct jobs D_1, D_2, D_3, D_4, D_5 need to pass through the three different machines M_1, M_2, M_3 respectively. Determine the sequence that will minimize the total elapsed time and find the idle time for each machine.

Machine/ jobs	D_1	D_2	D_3	D_4	D_5
M_1	(2,2.5,3,4.5,5; 0.6,0.4,0.5)	(3.5,4,5,5.5,6; 0.4,0.2,0.3)	(2,2.5,3,3.5,4; 0.6,0.2,0.3)	(3,4,5,6,7; 0.6,0.2,0.4)	(2,4,4.5,5,6; 0.5,0.3,0.2)
M_2	(0.5,1,2,2.5,4; 0.7,0.5,0.4)	(1.5,2,2.5,3,4; 0.7,0.2,0.4)	(1,2,3,4,5; 0.7,0.5,0.6)	(2,2.5,3,4.5,5; 0.6,0.4,0.5)	(1,2,2.5,3.5,4; 0.7,0.4,0.3)
M_3	(1,2,3,4,5; 0.6,0.5,0.4)	(3,4,5,6,7; 0.6,0.2,0.4)	(1,1.5,2.5,3,4; 0.6,0.4,0.5)	(4,5,5.5,6,7; 0.5,0.2,0.3)	(2,2.5,3,3.5,4; 0.7,0.5,0.3)

Method 1

Step 1 In this sequencing problem we see that all the elements are PNN. First we convert this number into crisp number using our developed score value $\widetilde{SC} = \frac{1}{10}(R_1 + R_2 + R_3 + R_4 + R_5) \times \{(1 - \pi^2 - \sigma^2) + (1 - \pi^2 - \rho^2)\}$ thus the problem becomes.

Machine/ jobs	D_1	D_2	D_3	D_4	D_5
M_1	1.48	3.72	1.72	2.70	2.95
M_1	0.61	1.066	0.62	1.48	1.01
M_1	1.30	2.70	1.04	3.77	1.02

Step 2 The optimum sequence can be obtained by converting the problem into that of two- motors by the following steps.

$Max(M_2) = 1.48, Min(M_1) = 1.48$. Thus, $Min(M_1) = Max(M_2)$ is satisfied.

We define two motors R and S such that the processing time on R and S are given by,

$R_i = M_{1_i} + M_{2_i}$ and $S_i = M_{2_i} + M_{3_i}, i = 1, 2, \ldots, 5$

Machine/ jobs	D_1	D_2	D_3	D_4	D_5
R	2.09	4.79	2.34	4.18	3.96
S	1.91	3.77	1.66	5.25	2.03

Step 3 We obtain the optimum sequence as.

D_4	D_2	D_5	D_1	D_3

Step 4

Job	M_1		M_2		M_3		Idle time		
	In	*Out*	*In*	*Out*	*In*	*Out*	M_1	M_2	M_3
D_4	0	2.7	2.7	4.18	4.18	7.95	-	2.7	4.18
D_2	2.7	6.42	6.42	7.43	7.95	10.65	-	2.24	-
D_5	6.42	9.37	9.37	10.38	10.65	11.67	-	1.94	-
D_1	9.37	10.85	10.85	11.46	11.67	12.97	-	0.47	-
D_3	10.85	12.57	12.57	13.19	13.19	14.23	14.23 – 12.57 = 1.66	1.11	0.22
								14.23 – 13.19 = 1.04	-
							1.66	9.5	4.4

Hence, total elapsed time = 14.23 hours. idle time for M_1 = 1.66 hours; idle time for M_2 = 9.5 hours; idle time for M_3 = 4.4 hours.

Method 2

Step 1 In this sequencing problem we see that all the elements are PNN. First we convert this number into crisp number using our developed score value (Chakraborty et al., 2019c) $\tilde{S}_{pen} = \frac{1}{15}(R_1 + R_2 + R_3 + R_4 + R_5) \times \{2 + \pi - \rho - \sigma\}$ thus the problem becomes,

Machine/ jobs	D_1	D_2	D_3	D_4	D_5
M_1	1.93	3.04	2.10	3.33	2.87
M_2	1.20	1.82	1.60	1.93	1.73
M_3	1.70	3.33	1.36	3.67	1.90

Step 2 The optimum sequence can be obtained by converting the problem into that of two-motors by the following steps

$$Max(M_2) = 1.93,\ Min(M_1) = 1.93. \text{ Thus, } Min(M_1) \geq Max(M_2) \text{ is satisfied.}$$

We define two motors R and S such that the processing time on R and S are given by,

$$R_i = M_{1_i} + M_{2_i} \quad \text{and} \quad S_i = M_{2_i} + M_{3_i},\ i = 1, 2 \ldots, 5$$

Machine/ jobs	D_1	D_2	D_3	D_4	D_5
R	3.13	4.86	3.70	5.26	4.60
S	2.90	5.15	2.96	5.60	3.63

Step 3 We obtain the optimum sequence as

D_2	D_4	D_5	D_3	D_1

Step 4

Job	M_1		M_2		M_3		*Idle time*		
	In	*Out*	*In*	*Out*	*In*	*Out*	M_1	M_2	M_3
D_2	0	3.04	3.04	4.86	4.86	8.19	-	3.04	4.86
D_4	3.04	6.37	6.37	8.3	8.3	11.97	-	1.51	0.11
D_5	6.37	9.24	9.24	10.97	11.97	13.87	-	0.94	-
D_3	9.24	11.34	11.34	12.94	13.87	15.23	-	0.37	-
D_1	11.34	13.27	13.27	14.47	15.23	16.93	16.93 – 13.27 = 3.66	0.33	-
								16.93 – 14.47 = 2.46	-
							3.66	8.65	4.97

Hence, total elapsed time = 16.93 hours, idle time for M_1 = 3.66 hours; idle time for M_2 = 8.65 hours; idle time for M_3 = 4.97 hours.

4.1 Discussion

In case of method 1 we actually applied the modified proposed score function and we observed that the total elapsed time is 14.23 hrs. But, when we applied the previous established score function in method 2 in the same problem, then the total elapsed time becomes 16.93 hrs. Also, since, the elapsed time denotes the waiting time of the problem thus, from the above two results we can say that our modified score function performs well instead of established score function, as the elapsed time is less than the method 2. So method 1 is a better approach rather than the last one.

Figure 1 Comparative results of idle time for two methods (see online version for colours)

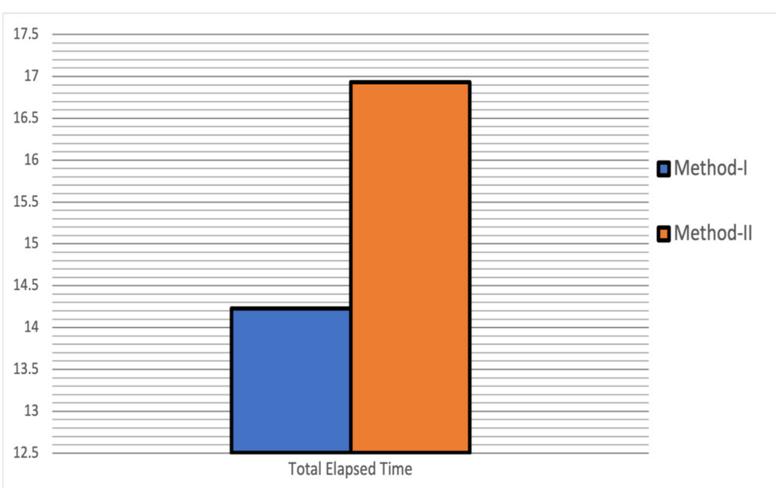
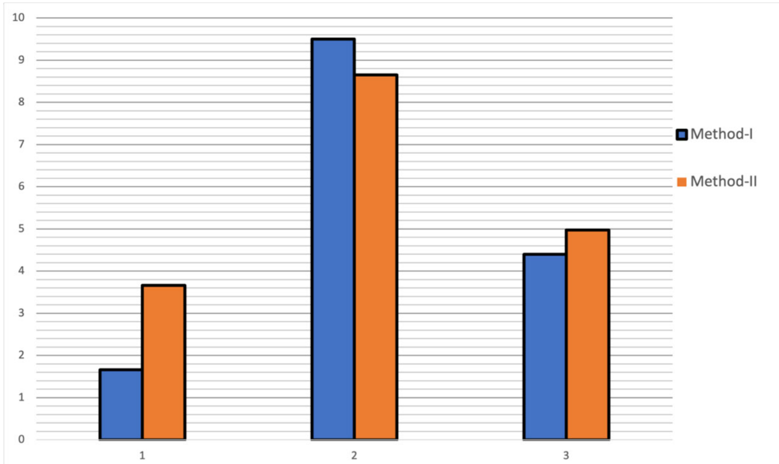


Figure 2 Comparative results of idle time for each machines in two methods (see online version for colours)



5 Conclusions

The thought of PNN is fascinating, knowledgeable and has a plenty scope of employment in diverse research arenas. In this research article, we dynamically raise the perception of PNN from special aspects. We established a modified score and accuracy function here in PNN arena. Additionally, we consider a job-sequencing problem in PNN environment and resolve the problem utilising the thought of score function. Lastly, we compared our proposed score function based result with the established score function based result, which gives fur more better solution than the established one.

Further, researchers can immensely apply this idea of neutrosophic number in numerous flourishing research fields like engineering problem, mobile computing problems, diagnoses problem, realistic mathematical modelling, social media problem, etc.

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