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Neutrosophic numbers in finding the shortest path using dynamic programming

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ABSTRACT

This paper proposed a method to find the shortest path in Neutrosophic environment using a dynamic programming algorithm. Applying Triangular, Trapezoidal and Pentagonal Neutrosophic numbers determine the shortest path. The shortest route is estimated for the acyclic network. Furthermore, we compared the results of Neutrosophic numbers and proved that the results are same.

1. Introduction

The NS is designated with elements having a acceptance degree, indeterminate membership and also non –membership. The pentagonal Neutrosophic number was developed by Said Broumi et al., in the year 2019 [1] which was applied in transportation environment. Neutrosophic Theory is a new subdivision which has been revolutionized from Intuitionistic Fuzzy Sets. It inculcates methods to sort out imprecise info problems. The data taken is incompatible. The elements of a Neutrosophic set have a degree of accuracy, the point of indeterminacy and degree of untruth. The idea of neutrosophy has put forth data which are always incomplete in characteristics. Figs. 1–4, Tables 1, 2

Single valued neutrosophic number is a generalization of a fuzzy number and intuitionistic fuzzy number. It takes in varied applications in many fields which is surrounded by indeterminate and incomplete data. The first part concentrates on the Introduction of the method proposed. Second part consists of the notation of a NS, SVNS, TNS and PNS. It also gives the score function of Trapezoidal Neutrosophic Set and Pentagonal Neutrosophic Set. The third part elucidates the details of the method being proposed for the problem. The fourth part gives a solution by identifying the smallest path for the trapezoidal neutrosophic network. The fifth part specifies the smallest path in the Pentagonal Neutrosophic network. The sixth part concludes with the solution for the above taken problem.

2. Neutrosophic preliminaries

2.1. Definition 1: neutrosophic set

" Let ηbe a space points with generic element in ηdenoted by y. Then a Neutrosophic set βin η

Is characterized by a truth membership function T_β,an indeterminacy membership function $I_\beta$and a falsity membership function F_β. The functions T_β, $I_\beta$and $F_\beta$are real standard or non– standard subsets of $[\ {}^-0, 1^+]$ that is $T_\beta : \eta \to [\ {}^-0, 1^+]$; $I_\beta : \eta \to [\ {}^-0, 1^+]$; $F_\beta : \eta \to [\ {}^-0, 1^+]$. It should be noted that there is no restriction on the sum of$T_\beta(y), I_\beta(y), F_\beta(y)$. That is $0 \leqslant T_\beta(y) + I_\beta(y) + F_\beta(y) \leqslant 3$."

2.2. Definition 2: single valued neutrosophic set

"Let ηbe a universal space points with generic element in ηdenoted by y. A single valued Neutrosophic set N is characterized by a

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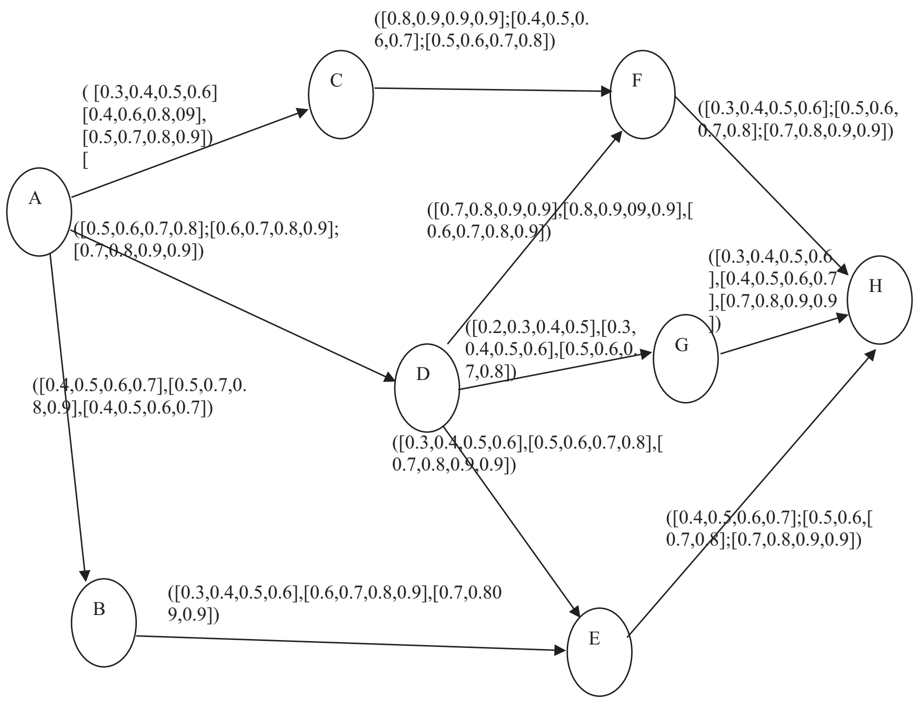

Fig 1. Trapezoidal Neutrosophic Network.

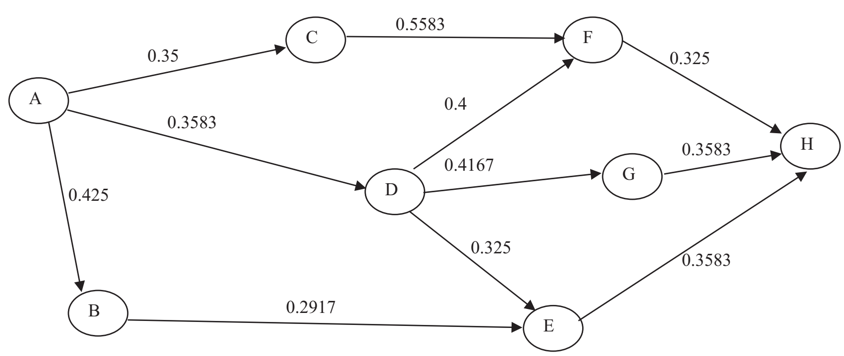

Fig 2. Trapezoidal Neutrosophic Network after Deneutrosophication.

truth membership function $T_N(y)$,an indeterminacy membership function $I_N(y)$and a falsity membership function$F_N(y)$ with $T_N(y)$, $I_N(y)$, $F_N(y)\in[0,1]$for all $y in \eta$".

2.3. Definition 3: single valued trapezoidal neutrosophic number

"A single valued trapezoidal Neutrosophic number $A=\{(a_1,b_1,c_1,d_1);(T_A,I_A,F_A)\}$ is a special neutrosophic set on the real number R, whose truth membership, indeterminate membership and falsity membership are as follows:

$$T_A(x)=\begin{cases}\frac{(x-a_1)T_a}{(b_1-a_1)},a_1\le x\le b_1\\ T_a,b_1\le x\le c_1\\ \frac{(d_1-x)T_a}{(d_1-c_1)},c_1\le x\le d_1\\ 0otherwise\end{cases}$$

$$I_A(x)=\begin{cases}\frac{(b_1-x)+I_a(x-a_1)}{(b_1-a_1)},a_1\le x\le b_1\\ I_a,b_1\le x\le c_1\\ \frac{(x-c_1)+I_a(d_1-x)}{(d_1-c_1)},c_1\le x\le d_1\\ 1otherwise\end{cases}$$

2.4. Definition 4: single valued pentagonal neutrosophic number [4]

"A single valued pentagonal Neutrosophic number $S=\{(m^1,n^1,o^1,p^1,q^1:\pi);(m^1,n^1,o^1,p^1,q^1:\rho);(m^1,n^1,o^1,p^1,q^1:\sigma)\}$

where π, ρ, σ ∈ [0,1]. The accuracy membership function($\tau\tilde{S}$): ■→ [0, π], the indeterminacy membership function ($\iota\tilde{S}$): ■→ [ρ, 1] and the falsity membership function ($\varepsilon\tilde{S}$): ■→ [σ, 1]"

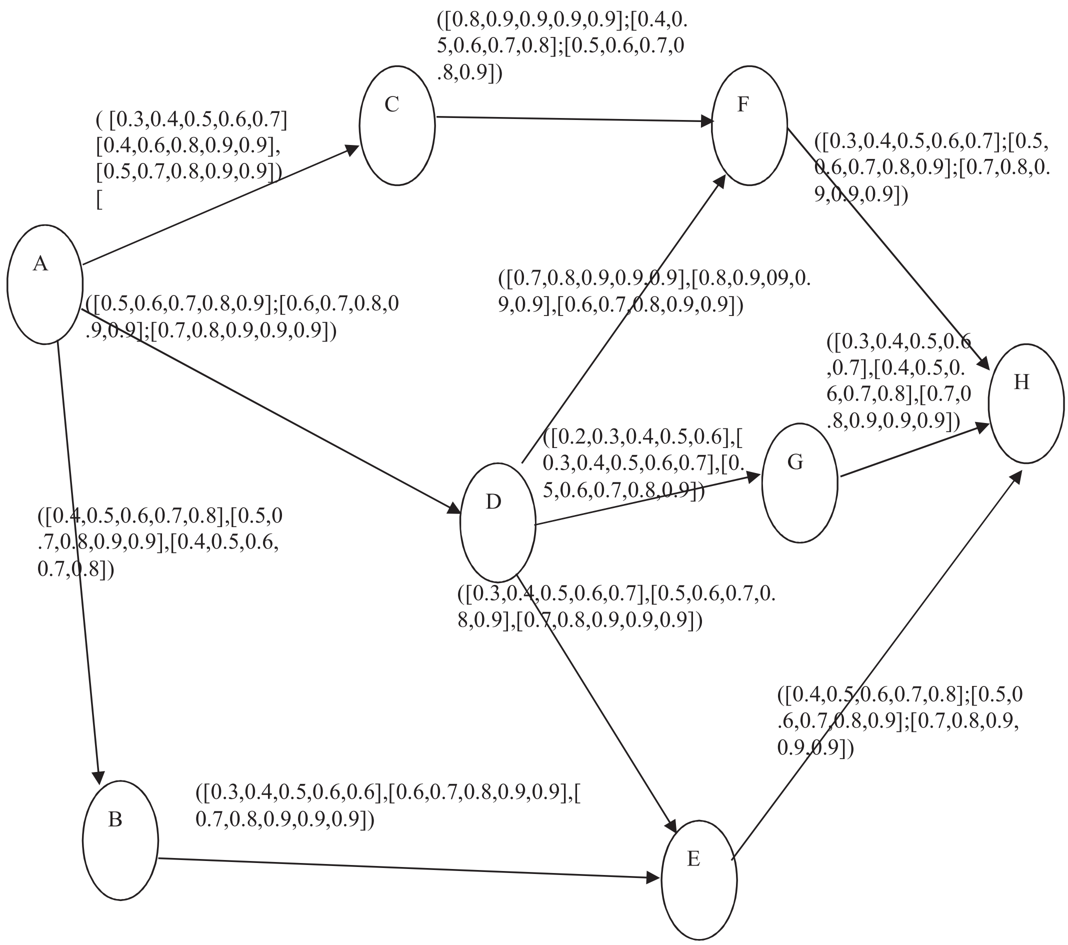

Fig 3. Pentagonal Neutrosophic Network.

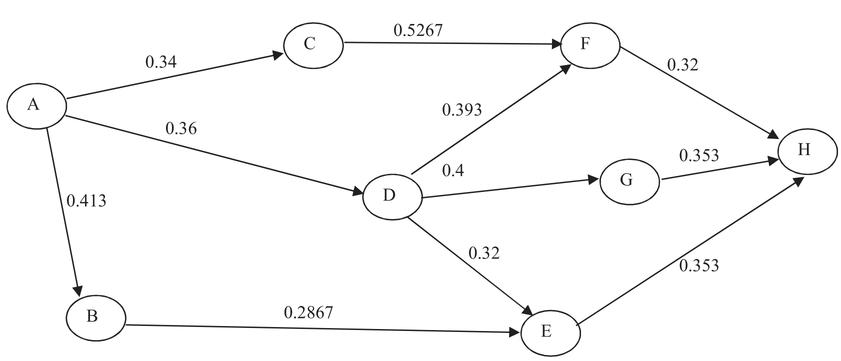

Fig 4. Pentagonal Neutrosophic Network after Deneutrosophication.

Table 1
Cost of Vertices.

Vertex	A	B	C	D	E	F	G	H
Cost	1.075	0.65	0.8833	0.725	0.3583	0.325	0.3583	0
Decision	D	E	F	G	H	H	H	H

Table 2
Cost of Vertices.

Vertex	A	B	C	D	E	F	G	H
Cost	1.033	0.6397	0.847	0.673	0.353	0.32	0.353	0
Decision	D	E	F	E	H	H	H	H

$$\tau_{s(x)} = \begin{cases} \tau_{sl1}(x) & m^1 \leqslant x < n^1 \\ \tau_{sl2}(x) & n^1 \leqslant x < o^1 \\ \mu & x = o^1 \\ \tau_{sr2}(x) & o^1 \leqslant x < p^1 \\ \tau_{sr1}(x) & p^1 \leqslant x < q^1 \\ 0 & otherwise \end{cases}$$

$$l_{s(x)} = \begin{cases} l_{sl1}(x) & m^2 \leqslant x < n^2 \\ l_{sl2}(x) & n^2 \leqslant x < o^2 \\ \upsilon & x = o^2 \\ l_{sr2}(x) & o^2 \leqslant x < p^2 \\ l_{sr1}(x) & p^2 \leqslant x < q^2 \\ 1 & otherwise \end{cases}$$

$$\varepsilon_{s(x)} = \begin{cases} \varepsilon_{sl1}(x) & m^3 \leqslant x < n^3 \\ \varepsilon_{sl2}(x) & n^3 \leqslant x < o^3 \\ \upsilon & x = o^3 \\ \varepsilon_{sr2}(x) & o^3 \leqslant x < p^3 \\ \varepsilon_{sr1}(x) & p^3 \leqslant x < q^3 \\ 1 & otherwise \end{cases}$$

2.5. Definition 5: score function of trapezoidal neutrosophic number

$$S(\tilde{n}) = \frac{1}{3}(2 + \frac{a+b+c+d}{4} - \frac{e+f+g+h}{4} - \frac{l+m+n+p}{4})$$

2.6. Definition 6: score function of pentagonal neutrosophic number

$$S(\tilde{n}) = \frac{1}{3}(2 + \frac{l_1+l_2+l_3+l_4+l_5}{5} - \frac{m_1+m_2+m_3+m_4+m_5}{5} - \frac{n_1+n_2+n_3+n_4+n_5}{5})$$

3. An algorithm for determining the shortest route

Step 1: We have taken a non-cyclic network. The edge weights are taken as Trapezoidal Neutrosophic numbers and Pentagonal Neutrosophic numbers.

Step 2: Score function of the Trapezoidal Neutrosophic number and Pentagonal Neutrosophic number are used to do the deneutrosophication of the edge weights.

Step 3: The dynamic programming is really useful when the network is of many stages. In this problem four stages are involved. The vertex set is divided into 4 stages. The edges will join vertices from one level to the succeeding level. On that point is but one vertex in the starting and the terminal phase. The path is selected by by its least cost.

Step 4: The process is starting from the fourth stage. The cost for the fourth stage will be zero.

Step 5: Move forward to the third stage. Three vertices are there in the Third stage. The cost of these nodes is calculated.

Step 6: Move forward to the Second stage. Second stage consists of three vertices. If more than one edge is getting away from a vertex, then consider the minimum cost. The cost is calculated using the following formula.

Cost (l, m) = min {c (m, k) + cost (l + 1, k)} where l represents the phase, m represents the node. k represents another node.

Step 7: Move forward to the initial phase. 3 edges comes out from the node 1. Consider the least cost. The decision has started from the initial node.. The idea of optimality is used to identify the smallest path. Agreeing to our conclusion, the smallest path is set up.

4. Trapezoidal Neutrosophic network

Allow us get hold of the Trapezoidal Neutrosophic network where the edge weights are taken as Trapezoidal Neutrosophic set. The mark function is being applied for deneutrosophication..

Stage 4: cost (D,H) = 0

Stage 3:cost (C, E) = 0.3583, cost (C, G) = 0.3583, cost (C,F) = 0.325

Stage 2:cost (B, C) = c (C, F) + cost(D,F) = 0.5583 + 0.325 = 0.8833

cost (B, D) = min{c(D,F) + cost(C,F), c(D,G) + cost(C,G),c(D,E) + cost(C,E)}

=min{0.4 + 0.35, 0.4167 + 0.3583, 0.325 + 0.3583}

= min {0.725, 0.775, 0.6833} = 0.725

Cost(B,B) = c (B,D) + cost(C,E) = 0.2917 + 0.3583 = 0.65

Stage 1:

cost (A,A) = min{c(A,C) + cost (B,C), c(A,D) + cost(B,D),c(A,B) + cost(B,B)}

=min{0.35 + 0.8833, 0.3483 + 0.75,0.425 + 0.65}

=min{1.2333,1.0733,1.075} = 1.073

Decisions taken:

d(A,A) = B

d(B,B) = E

d(C,E) = H

The shortest path is $A \to D \to G \to H$**.**

5. Pentagonal Neutrosophic network

Allow us get hold of the pentagonal neutrosophic network where the edge weights are considered as a Pentagonal Neutrosophic set. The deneutrosophication has done by score function.

Stage 4: cost (D, H) = 0

Stage 3:cost (C, E) = 0.32, cost (C, G) = 0.353, cost (C, F) = 0.353

Stage 2:cost (B, C) = c (C, F) + cost(D,F) = 0.527 + 0.32 = 0.847

cost (B, D) = min{c(D,F) + cost(C,F), c(D,G) + cost(C,G),c(D,E) + cost(C,E)}

=min{0.393 + 0.32, 0.4 + 0.353, 0.32 + 0.353}

= min {0.713,0.753,0.673} = 0.673

Cost (B,B) = c (B,D) + cost(C,E) = 0.2867 + 0.353 = 0.6397

Stage 1:

cost (A,A) = min{c(A,C) + cost (B,C), c(A,D) + cost(B,D),c(A,B) + cost(B,B)}

=min{0.34 + 0.847, 0.36 + 0.673, 0.413 + 0.6397}

=min{1.187,1.033,1.0527} = 1.003

Decisions taken:

d(A,A) = D

d(D,B) =

d(C,E) = H

The Shortest Path is $A \to D \to G \to H$**.**

6. Conclusion

We applied the Dynamic programming in the network with many stages using the Trapezoidal Neutrosophic network and the pentagonal Neutrosophic network. We conclude that the least cost path for both the network is $A \rightarrow D \rightarrow G \rightarrow H$. The existing network can be compared with other neutrosophic network.

CRediT authorship contribution statement

N. Jose Pravin Praveena: Conceptualization, Methodology. **S. Ghousia Begum:** Formal analysis, Writing - original draft. **Ganesh Kumar Thakur:** Supervision, Validation. **Bandana Priya:** Investigation, Data curation. **Chirag Goyal:** Visualization, Resources, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Further Reading

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