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# Single Valued Neutrosophic Coloring

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**Abstract:** Neutrosophic set was introduced by Smarandache in 1998. Due to some real time situation, decision makers deal with uncertainty and inconsistency to identify the best result. Neutrosophic concept helps to investigate the vague or indeterminacy values. Graph structures used to reduce the complications in solving the system of equations for finding the decision of some real-life problems. In this research study, we introduced the single-valued neutrosophic coloring concept. We introduce various notions, single valued neutrosophic vertex coloring, single valued neutrosophic edge coloring, and single valued neutrosophic total coloring and support those definitions with some examples.

**Keywords:** single-valued neutrosophic graphs; single-valued neutrosophic vertex coloring; single-valued neutrosophic edge coloring; single-valued neutrosophic total coloring.

## 1. Introduction

Graph theory plays a vital role in real time problems Graph represents the connection among the points by lines and is the useful tool to solve the network problems. It is applicable in many fields such as computer science, physical science, electrical communication engineering, economics and Operation Research etc. In 1852, Francis Guthrie's four-color conjecture gave the sparkle for the new branch, graph coloring in graph theory. Graph coloring is assigning the color to the vertices or edges or both vertices and edges of the graph based on some conditions. After three decades got the solution to Guthrie's conjecture. Graph coloring technique used in many areas like telecommunication, scheduling, computer networks etc. Sometime in real-life have to deal with imprecise data and uncertain relation between points, in that case fuzzy technique where came. In 1965, Fuzzy set theory was introduced by Zadeh [39] and further work on fuzzy graph theory developed by A. Rosenfeld [33] in 1975. The fuzzy chromatic number was introduced by Munoz et al. [36] in 2004 and extended by C.Eslahchi and B.N.Onagh [23] in 2006. In 2009, S.Lavanya and R.Sattanathan [30] introduced the concept fuzzy total coloring. In 2014, Anjaly Kishore, M.S.Sunitha [7] discussed the strong chromatic number of fuzzy graphs in their research paper.

Intuitionistic fuzzy sets are dealing membership and non-membership data. Kassimir T.Atanassov [13] introduced the concept of intuitionistic fuzzy sets in 1986 and intuitionistic fuzzy graph in 1999. Ismail and Rifayathali [28] discussed the coloring of intuitionaistic fuzzy graphs using ($\alpha$, β) cuts in 2015, Rifayathali et al. [32] discussed intuitionistic fuzzy coloring and strong intuitionistic fuzzy coloring in 2017 and 2018.

Vague set concept introduced by Gau and Buehrer [26] in 1993 and in 2014, Akram et al. [11] discussed vague graphs and further work extended by Borzooei et al. [14, 15], Vertex and Edge coloring of Vague graphs were introduced by Arindam Dey et al [12] in 2018.

In all real-time cases, the membership and non-membership values are not enough to find the result. Sometimes the vague or indeterminacy qualities need to be considered for the decision making, in that case intuitionistic fuzzy logic insufficient to give the solution. This situation reasoned for to move the new concept, F.Smarandache came with a solution"Neutrosophic logic". Neutrosophic logic play a vital role in several of the real valued problems like law, medicine, industry, finance, engineering, IT, etc.

Neutrosophic set was introduced by F.Smarandache [35] in 1998, Neutrosophic set a generalisation of the intuitionistic fuzzy set. It consists truth value, indeterminacy value and false values.Wang et al. [38] worked on Single valued neutrosophic sets in 2010. Strong Neutrosophic graph and its properties were introduced and discussed by Dhavaseelan et al. [25] in 2015 and Single valued neutrosophic concept introduced in 2016 by Akram and Shahzadi [8, 9, 10]. Broumi et al. [16, 17, 18, 19, 20, 21, 22] extended their works in Single valued neutrosophic graphs, Isolated single valued graphs, Uniform single valued graphs, Interval valued neutrosophic graphs (IVNG) and Bipolar neutrosophic graphs. Dhavaseelan et al. [24] in 2018, discussed Single valued co-neutrosophic graphs in their paper. Sinha et al. [34] extended the single valued work for signed digraphs in 2018 and Vasile [37] proposed five penta-valued refined neutrosophic indexes representation in his work. In 2019, jan et al. in their paper [29] have reviewed the following definitions: Interval-Valued Fuzzy Graphs (IVFG), Interval-Valued Intuitionistic Fuzzy Graphs (IVIFG), Complement of IVFG, SVNG, IVNG and the complement of SVNG and IVNG. They have modified those definitions, supported with some examples. Neutrosophic graphs happen to play a vital role in the building of neutrosophic models. Also, these graphs can be used in networking, Computer technology, Communication, Genetics, Economics, Sociology, Linguistics, etc., when the concept of indeterminacy is present.

Abdel-Basset et al. used Neutrosophic concept in their papers [1, 2, 3, 4, 5, 6, 31] to find the decisions for some real-life operation research and IoT-based enterprises in 2019. The above papers given the idea to interlink the graph coloring concept in SVNG when deal with vague or indeterminacy qualities.

In this research paper, we introduced the concept of single valued neutrosophic vertex coloring, single valued neutrosophic edge coloring and single valued neutrosophic total coloring of single valued neutrosophic graph and also Strong and Complete Single valued neutrosophic graph coloring are discussed with examples.

Definition 1.1. [35]

Let X be a space of points(objects). A neutrosophic set A in X is characterized by truth-membership function $t_A(x)$ , an indeterminacy-membership function $i_A(x)$ and a falsity-membership function $f_A(x)$. The functions $t_A(x)$, $i_A(x)$, and $f_A(x)$, are real standard or non-standard subsets of $]0^-, 1^+[$. That is, $t_A(x): X \to ]0^-, 1^+[$, $i_A(x): X \to ]0^-, 1^+[$ and $f_A(x): X \to ]0^-, 1^+[$ and $0^- \leq t_A(x) + i_A(x) + f_A(x) \leq 3^+$.

Definition 1.2. [9]

A single-valued neutrosophic graphs (SVNG) G = (X, Y) is a pair where X: N → [0,1] is a single-valued neutrosophic set on N and Y: N × N → [0,1] is a single-valued neutrosophic relation on N such that

$$t_Y(xy) \leq \min\{t_X(x), t_X(y)\},$$

$$i_Y(xy) \leq \min\{i_X(x), i_X(y)\},$$

$$f_Y(xy) \leq \max\{f_X(x), f_X(y)\},$$

for all x,y ∈ N. X and Y are called the single-valued neutrosophic vertex set of G and the single-valued neutrosophic edge set of G, respectively. A single-valued neutrosophic relation Y is said to be symmetric if $t_Y(xy) = t_Y(yx)$, $i_Y(xy) = i_Y(yx)$ and $f_Y(xy) = f_Y(yx)$, for all x,y ∈ N. Single-valued neutrosophic be abbreviated here as SVN.

Definition 1.3. [10]

The complement of a SVNG G = (X, Y) is a SVNG $\bar{G} = (\bar{X}, \bar{Y})$, where

1. $\bar{X} = X$
2. $\bar{t_X}(x) = t_X(x), \bar{i_X}(x) = i_X(x), \bar{f_X}(x) = f_X(x)\ for\ all\ x \in X$
3. $\bar{t_X}(xy) = \begin{cases} \min\{t_X(x), t_X(y)\}\ if\ \ t_Y(xy) = 0 \\ \min\{t_X(x), t_X(y)\} - t_Y(xy)\ if\ \ t_Y(xy) > 0 \end{cases}$

$$\bar{i_X}(xy) = \begin{cases} \min\{i_X(x), i_X(y)\}\ if\ \ i_Y(xy) = 0 \\ \min\{i_X(x), i_X(y)\} - i_Y(xy)\ if\ \ i_Y(xy) > 0 \end{cases}$$

$$\bar{f_X}(xy) = \begin{cases} \max\{f_X(x), f_X(y)\}\ if\ \ f_Y(xy) = 0 \\ \max\{f_X(x), f_X(y)\} - f_Y(xy)\ if\ \ f_Y(xy) > 0 \end{cases}$$

for all $x, y \in X$.

## 2. Single-Valued Neutrosophic Vertex Coloring (SVNVC)

In this section, we have developed SVNVC and this coloring has verified through some examples of SVNG, CSVNG and SSVNG. Also discussed some theorems.

Definition 2.1.

A family $\Gamma = \{\gamma_1, \gamma_2, \dots, \gamma_k\}$ of SVN fuzzy set is called a k-SVNVC of a SVNG G = (X, Y) if

1. $\vee \gamma_i(x) = X,\ \forall x \in X$

2. $\gamma_i \wedge \gamma_j = 0$

3. For every incident vertices of edge xy of G, $\min\{\gamma_i(m_1(x)), \gamma_i(m_1(y))\} = 0$, $\min\{\gamma_i(i_1(x)), \gamma_i(i_1(y))\} = 0\ and\ \max\{\gamma_i(n_1(x)), \gamma_i(n_1(y))\} = 1, (1 \leq i \leq k)$.

This k-SVNVC of G is denoted by $\chi_v(G)$, is called the SVN chromatic number of the SVNG G.

Example 2.2.

Consider the SVNG G = (X,E) with SVN vertex set $X = \{x_1, x_2, x_3, x_4, x_5\}$ and SVN edge set $E = \{X_i X_j | ij = 12,14,15,23,24,25,34,35,45\}$ the membership functions defined as,

$$\left(m_1(x_i), i_1(x_i), n_1(x_i)\right) = \begin{cases} (0.3,0.2,0.6)\ for\ i = 1,2 \\ (0.7,0.1,0.2)\ for\ i = 3 \\ (0.2,0.1,0.7)\ for\ i = 4 \\ (0.5,0.1,0.7)\ for\ i = 5 \end{cases}$$

$$\left(m_2(x_i x_j), i_2(x_i x_j), n_2(x_i x_j)\right) = \begin{cases} (0.3,0.2,0.6)\ for\ ij = 12 \\ (0.2,0.1,0.7)\ for\ ij = 14,24,34,45 \\ (0.3,0.1,0.6)\ for\ ij = 15,23,25 \\ (0.5,0.1,0.7)\ for\ ij = 35 \end{cases}$$

Let $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$ be a family of SVN fuzzy sets defined on X as follows:

$$\gamma_1(x_i) = \begin{cases} (0.3,0.2,0.6)\ for\ i = 1,3 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_2(x_i) = \begin{cases} (0.7,0.1,0.2)\ for\ i = 2 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_3(x_i) = \begin{cases} (0.5,0.1,0.7)\ for\ i = 4 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_4(x_i) = \begin{cases} (0.2,0.1,0.7)\ for\ i = 5 \\ (0,0,1)\ for\ others \end{cases}$$

Hence the family $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$ fulfilled the conditions of SVNVC of the graph G. Any families below four points could not satisfy our definition. Hence the SVN chromatic number $\chi_v(G)$ of the above example is 4.

Definition 2.3.

A SVNG G = (X, Y) is called complete single-valued neutrosophic graph (CSVNG) if the following conditions are satisfied:

$$t_Y(xy) = \min\{t_X(x), t_X(y)\},$$

$$i_Y(xy) = \min\{i_X(x), i_X(y)\},$$

$$f_Y(xy) = \max\{f_X(x), f_X(y)\},$$

for all x,y ∈ X.

Definition 2.4.

A SVNG G = (X, Y) is called strong single-valued neutrosophic graph (SSVNG) if the following conditions are satisfied:

$$t_Y(xy) = \min\{t_X(x), t_X(y)\},$$

$$i_Y(xy) = \min\{i_X(x), i_X(y)\},$$

$$f_Y(xy) = \max\{f_X(x), f_X(y)\},$$

for all (x,y) ∈ Y .

Example 2.5.

Consider the SSVNG G = (X,Y) with SVN vertex set $X = \{x_1, x_2, x_3, x_4, x_5\}$ and SVN edge set $Y = \{x_i x_j | ij = 12,15,23,34,45\}$ the membership functions defined as,

$$\big(m_1(x_i), i_1(x_i), n_1(x_i)\big) = \begin{cases} (0.1,0.2,0.9)\ for\ i = 1 \\ (0.6,0.7,0.4)\ for\ i = 2 \\ (0.3,0.3,0.7)\ for\ i = 3 \\ (0.7,0.8,0.2)\ for\ i = 4 \\ (0.5,0.5,0.6)\ for\ i = 5 \end{cases}$$

$$\Big(m_2(x_i x_j), i_2(x_i x_j), n_2(x_i x_j)\Big) = \begin{cases} (0.1,0.2,0.9)\ for\ ij = 12,15 \\ (0.3,0.3,0.7)\ for\ ij = 23,34 \\ (0.5,0.5,0.6)\ for\ ij = 45 \end{cases}$$

Let $\Gamma = \{\gamma_1, \gamma_2, \gamma_3\}$ be a family of SVN fuzzy sets defined on X as follows:

$$\gamma_1(x_i) = \begin{cases} (0.1,0.2,0.9)\ for\ i = 1 \\ (0.3,0.3,0.7)\ for\ i = 3 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_2(x_i) = \begin{cases} (0.6,0.7,0.4)\ for\ i = 2 \\ (0.7,0.8,0.2)\ for\ i = 4 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_3(x_i) = \begin{cases} (0.5,0.5,0.6)\ for\ i = 5 \\ (0,0,1)\ for\ others \end{cases}$$

Hence the family $\Gamma = \{\gamma_1, \gamma_2, \gamma_3\}$ fulfilled the conditions of Strong SVNVC of the graph G. Any families below three points could not satisfy our definition. Hence the SSVN chromatic number $\chi_v(G)$ of the above example is 3.

Example 2.6.

Consider the CSVNG G = (X,Y) with SVN vertex set $X = \{x_1, x_2, x_3, x_4, x_5\}$ and SVN edge set $Y = \{x_i x_j | ij = 12,13,14,23,24,34\}$ the membership functions defined as,

$$\big(m_1(x_i), i_1(x_i), n_1(x_i)\big) = \begin{cases} (0.7,0.7,0.1)\ for\ i = 1 \\ (0.6,0.7,0.3)\ for\ i = 2 \\ (0.3,0.3,0.7)\ for\ i = 3 \\ (0.1,0.1,0.8)\ for\ i = 4 \end{cases}$$

$$\Big(m_2(x_i x_j), i_2(x_i x_j), n_2(x_i x_j)\Big) = \begin{cases} (0.6,0.7,0.3)\ for\ ij = 12 \\ (0.3,0.3,0.7)\ for\ ij = 13,23 \\ (0.1,0.1,0.8)\ for\ ij = 14,24,34 \end{cases}$$

Let $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$ be a family of SVN fuzzy sets defined on X as follows:

$$\gamma_1(x_i) = \begin{cases} (0.7,0.7,0.1)\ for\ i = 1 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_2(x_i) = \begin{cases} (0.6,0.7,0.3)\ for\ i = 2 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_3(x_i) = \begin{cases} (0.3,0.3,0.7)\ for\ i = 3 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_4(x_i) = \begin{cases} (0.1,0.1,0.8)\ for\ i = 4 \\ (0,0,1)\ for\ others \end{cases}$$

Hence the family $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$ fulfilled the conditions of complete SVNVC of the graph G. Any families below four points could not satisfy our definition. Hence the SVN chromatic number $\chi_v(G)$ of the above example is 4.

Theorem 2.7.

For any graph CSVNG with n vertices, $\chi_v(G) = n$.

Proof:

By the definition of CSVNG, all the vertices are adjacent to each other. Each color class contains exactly one vertex with the value ($t_X$(x), $t_X$(x),$t_X$(x))> 0, thus remaining vertices are with the value ($t_X$(x), $t_X$(x),$t_X$(x)) = 0. Hence $\chi_v(G) = n$.

Theorem 2.8.

For any SSVNG G, then $\overline{\overline{\chi_v}}(G) = \chi_v(G)$.

Proof. It is obvious.

## 3. Single-Valued Neutrosophic Edge Coloring (SVNEC)

In this section, we introduced and discussed SVNEC with an example and theorems.

Definition 3.1.

A family $\Gamma = \{\gamma_1, \gamma_2, \dots, \gamma_k\}$ of SVN fuzzy set is called a k-SVNEC of a SVNG G = (X,Y) if

1. $\vee\, \gamma_i(xy) = Y,\ \forall xy \in Y$
2. $\gamma_i \wedge \gamma_j = 0$
3. For every strong edge xy of G, $\min\{\gamma_i(m_2(xy))\} = 0,\ \min\{\gamma_i(i_2(xy))\} = 0\ and\ \max\{\gamma_i(n_2(xy))\} = 1, (1 \le i \le k)$.

This k-SVNEC of G is denoted by$\chi_e(G)$, is called the SVN chromatic number of the SVNG G.
Example 3.2.
Consider the SVNG G = (X,Y) with SVN vertex set $X = \{x_1, x_2, x_3, x_4\}$ and SVN edge set $Y = \{x_i x_j | ij = 12,13,14,23,24,34\}$ the membership functions defined as,

$$\left(m_1(x_i), i_1(x_i), n_1(x_i)\right) = \begin{cases}(0.3,0.1,0.6)\ for\ i = 1\\(0.2,0.1,0.4)\ for\ i = 2\\(0.5,0.2,0.4)\ for\ i = 3\\(0.4,0.1,0.4)\ for\ i = 4\end{cases}$$

$$\left(m_2(x_i x_j), i_2(x_i x_j), n_2(x_i x_j)\right) = \begin{cases}(0.2,0.1,0.4)\ for\ ij = 12,23,24\\(0.3,0.1,0.6)\ for\ ij = 13,14\\(0.4,0.1,0.4)\ for\ ij = 24\end{cases}$$

Let $\Gamma = \{\gamma_1, \gamma_2, \gamma_3\}$ be a family of SVN fuzzy sets defined on Y as follows:

$$\gamma_1(x_i x_j) = \begin{cases}(0.2,0.1,0.4)\ for\ i = 12,34\\(0,0,1)\ for\ others\end{cases}$$

$$\gamma_2(x_i x_j) = \begin{cases}\left((0.3,0.1,0.6)\right)\ for\ i = 14,23\\(0,0,1)\ for\ others\end{cases}$$

$$\gamma_3(x_i x_j) = \begin{cases}(0.4,0.1,0.4)\ for\ i = 13,24\\(0,0,1)\ for\ others\end{cases}$$

Hence the family $\Gamma = \{\gamma_1, \gamma_2, \gamma_3\}$ fulfills the conditions of SVNEC of SVNG. Any families below three members could not satisfy our definition. Hence, the SVN chromatic number $\chi_e(G)$ of the above example is 3.

## 4. Single-Valued Neutrosophic Total Coloring (SVNTC)

In this section, we defined SVNTC supported by an example.

Definition 4.1.

A family $\Gamma = \{\gamma_1, \gamma_2, \dots, \gamma_k\}$ of SVN fuzzy sets on the SVN vertex set X is called a k-SVNTC of SVNG G = (X, Y) if

1. $\vee\, \gamma_i(x) = X,\ \forall x \in X$ and $\vee\, \gamma_i(xy) = Y,\ \forall xy \in Y$
2. $\gamma_i \wedge \gamma_j = 0$
3. For every incident vertices of edge xy of G, $\min\{\gamma_i(m_1(x)), \gamma_i(m_1(y))\} = 0$, $\min\{\gamma_i(i_1(x)), \gamma_i(i_1(y))\} = 0$ *and* $\max\{\gamma_i(n_1(x)), \gamma_i(n_1(y))\} = 1, (1 \le i \le k)$. For every strong edge xy of G, $\min\{\gamma_i(m_2(xy))\} = 0$, $\min\{\gamma_i(i_2(xy))\} = 0$ *and* $\max\{\gamma_i(n_2(xy))\} = 1, (1 \le i \le k)$.

This k-SVNTC of G is denoted by $\chi_t(G)$, is called the SVN chromatic number of the SVNG G.

Example 4.2.

Consider the SVNG G = (X,Y) with SVN vertex set $X = \{x_1, x_2, x_3, x_4, x_5\}$ and SVN edge set $Y = \{x_i x_j | ij = 12,13,14,15,23,24,25,34,35,45\}$ the membership functions defined as,

$$\left(m_1(x_i), i_1(x_i), n_1(x_i)\right) = \begin{cases}(0.3,0.1,0.7)\ for\ i = 1\\(0.5,0.3,0.5)\ for\ i = 2\\(0.4,0.2,0.6)\ for\ i = 3\\(0.8,0.6,0.2)\ for\ i = 4\\(0.7,0.5,0.3)\ for\ i = 5\end{cases}$$

$$\left(m_2(x_i x_j), i_2(x_i x_j), n_2(x_i x_j)\right) = \begin{cases}(0.3,0.1,0.7)\ for\ ij = 12,13,14,15\\(0.8,0.6,0.2)\ for\ ij = 45\\(0.4,0.2,0.6)\ for\ ij = 23,24,25\\(0.5,0.3,0.5)\ for\ ij = 34,35\end{cases}$$

Let $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5\}$ be a family of SVN fuzzy sets defined on Y as follows:

$$\gamma_1(x_i) = \begin{cases} (0.3,0.1,0.7)\ for\ i = 1 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_2(x_i) = \begin{cases} (0.5,0.3,0.5)\ for\ i = 2 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_3(x_i) = \begin{cases} (0.4,0.2,0.6)\ for\ i = 3 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_4(x_i) = \begin{cases} (0.8,0.6,0.2)\ for\ i = 4 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_5(x_i) = \begin{cases} (0.7,0.5,0.3)\ for\ i = 5 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_1(x_i x_j) = \begin{cases} (0.3,0.1,0.7)\ for\ i = 12 \\ (0.5,0.3,0.5)\ for\ i = 35 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_2(x_i x_j) = \begin{cases} (0.3,0.1,0.7)\ for\ i = 13 \\ (0.4,0.2,0.6)\ for\ i = 24 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_3(x_i x_j) = \begin{cases} (0.3,0.1,0.7)\ for\ i = 14 \\ (0.4,0.2,0.6)\ for\ i = 25 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_4(x_i x_j) = \begin{cases} (0.8,0.6,0.2)\ for\ i = 45 \\ (0.4,0.2,0.6)\ for\ i = 23 \\ (0,0,1)\ for\ others \end{cases}$$

$$\gamma_5(x_i x_j) = \begin{cases} (0.3,0.1,0.7)\ for\ i = 15 \\ (0.5,0.3,0.5)\ for\ i = 34 \\ (0,0,1)\ for\ others \end{cases}$$

Hence the family $\Gamma = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5\}$ fulfills the conditions of SVNTC of SVNG. Any families below five members could not satisfy our definition. Hence the SVN chromatic number $\chi_t(G)$ of the above example is 5.

## 5. **Conclusions**

Single Valued Neutrosophic Coloring concept introduced in this paper. Single valued neutrosophic vertex coloring, single valued neutrosophic edge coloring and single valued neutrosophic total coloring are defined. All thus definitions are developed and supported by some of the examples. In future, it will be extended to examine the theory of SVNC with the irregular colorings of graphs.

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