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different process when the compare to FCM. Usually the FCM gives only the ON-OFF position. But this Triangular Fuzzy Cognitive Maps is more precise and it gives the ranking for the causes of the problem by using the weightage of the attribute.

3. BASIC NOTIONS OF TrFCMs

Definition 3.1. When the nodes of the TrFCM are fuzzy sets then they are called as fuzzy triangular nodes.
Definition 3.2. Triangular FCM with edge weights or causalities from the set {-1, 0, 1} are called simple Triangular FCMs.
Definition 3.3. A Triangular Fuzzy Cognitive maps (TrFCM) is a directed graph with concepts like policies, events etc, as nodes and causalities as edges, It represents causal relationships between concepts.
Definition 3.4. When there is a feedback in anTrFCM, i.e., when the causal relation flow through a cycle in a revolutionary way, the TrFCM is called a dynamical system.
Definition 3.5. If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider a TrFCM with the TrFCM with TrC1, TrC2,……,TrCn nodes.
Definition 3.6. If the TrFCM settles down with a state vector repeating in the form $A_1 \rightarrow A_2 \rightarrow \cdots A_i \rightarrow A_1$ then this equilibrium is called a limit cycle.

Linguistic values of Triangular Fuzzy Number

Table 1: The linguistic values

Linguistic values	Weightage of TrFCM	Average of TrFCM
Very low	(0, 0, 0.25)	0.08
Low	(0, 0.25, 0.50)	0.25
Medium	(0.25, 0.50, 0.75)	0.50
High	(0.50, 0.75, 1)	0.75
Very High	(0.75, 1, 1)	0.92

4. MATHEMATICAL FORMULATION

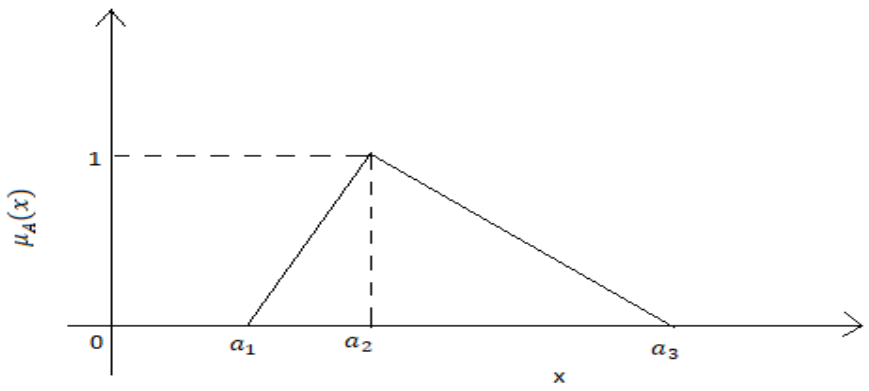


Figure1.1: Triangular Fuzzy number

4.1 Triangular Fuzzy number

A fuzzy number represented with three points as follows: $\tilde{A} = (a_1, a_2, a_3)$. This representation is interpreted as membership functions and holds the following conditions

(i) a_1 to a_2 is increasing function
(ii) a_2 to a_3 is decreasing function
(iii) $a_1 \leq a_2 \leq a_3$.

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The membership function defined as

$$\mu_A(x) = \begin{cases} 0, & for\ x < a_1 \\ \frac{x-a_1}{a_2-a_1}, & for\ a_1 \le x \le a_2 \\ \frac{a_3-x}{a_3-a_2}, & for\ a_2 \le x \le a_3 \\ 0, & for\ x > a_3 \end{cases}$$

4.2 Arithmetic Operation of Triangular Fuzzy Number

For arbitrary triangular fuzzy numbers $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ and $* = \{+, -, \times, \div\}$ the arithmetic operations on the triangular fuzzy numbers are defined by $\tilde{A} * \tilde{B} = \{a_i * b_j / a_i \in \tilde{A}, b_j \in \tilde{B}\}$. In particular, for any two triangular fuzzy numbers $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$, we define

(i) Addition (+) : $\tilde{A} + \tilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$

(ii) Subtraction(-) : $\tilde{A} + \tilde{B} = (a_1 - b_1, a_2 - b_2, a_3 - b_3)$

(iii) Multiplication($\otimes$) : $k \otimes A = (ka_1, ka_2, ka_3)$, $k \in R$, $k \ge 0$

$A \otimes b = (a_1 b, a_2 b, a_3 b)$, $a_1 \ge 0$, $a_2 \ge 0$, $a_3 \ge 0$

(iv) Division ($\oslash$) : $A^{(-1)} = (a_1, a_2, a_3)^{-1} \cong \left(\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1}\right)$,

$a_1 > 0, a_2 > 0, a_3 > 0$

$A \oslash B \cong \left(\frac{a_1}{c_2}, \frac{b_1}{b_2}, \frac{c_1}{a_2}\right)$, $a_1 \ge 0, a_2 \ge 0$

5. A RANKING ANALYSIS OF REASON FOR DRINKING TEA USING TrFCM METHOD

A field study was conducted to find out "The reasons behind Tea's popularity using Triangular Fuzzy Cognitive Map". The following data are taken from individuals of different age peoples.

5.1 The following 10 concepts are taken based on survey and interview

TrC_1 – Tea contains antioxidants
TrC_2– Stressless
TrC_3– Boosts energy
TrC_4 – Reduce Headache
TrC_5 – Weight loss
TrC_6 – Tea may reduce the risk of cancer
TrC_7 – Herbal tea may help the digestive system
TrC_8 – Boosts brain health
TrC_9 – Skin saver
TrC_{10} – Tradition and Habit

5.2 Algorithm for Triangular Fuzzy Cognitive Maps (TRFCM) Method

Step 1: Prepare a n x n connection matrix.
Step 2: Prepare the maximum weightage of the matrix using $T_r(M)$
Step 3: Find the limit cycle.
Let $T_rC_1, T_rC_2 \cdots T_rC_{10}$ be the nodes of a TrFCM. Here $T_r(M)$ be an adjacency matrix.
Consider the instantaneous state vector as $A_1 = (1, 0, 0, \ldots 0)$ for $A_1T_r(M)$ is switched ON.
$A_1T_r(M) = a_1, a_2, \ldots a_n$ will get a Triangular vector.
The threshold operation is denoted by $(\rightarrow)A_1T_r(M)$ Max (weight).
Suppose $A_1T_r(M)$ Max (weight) = A_2 then consider $A_2T_r(M)$ weight is the ON attribute Triangular vector.
Find $A_2T_r(M)$.
This procedure is repeated till we get a limit cycle or a fixed point.

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5.3 Methods of Determination of the Hidden Pattern of Triangular Fuzzy Cognitive Maps (TRFCM):

Step 1: In this step prepare a fuzzy matrix is called the Connection matrix by using linguistic variables " Very Low" (VL), " Low" (L), " Medium" (M), "Very High" (VH) and "High" (H) respectively.

Matrix 1.1: Connection matrix of Tr (M)

$$\begin{bmatrix} 0 & M & H & VH & VL & M & H & L & M & H \\ M & 0 & H & VH & L & VL & M & H & L & M \\ L & H & 0 & VH & L & L & M & VL & VL & L \\ VL & VH & H & 0 & M & L & H & H & L & H \\ L & VH & M & H & 0 & VL & H & M & L & L \\ M & H & H & VH & M & 0 & H & M & VL & L \\ M & H & H & VH & L & M & 0 & H & VL & L \\ L & VH & L & H & VL & L & L & 0 & M & L \\ L & H & M & VH & VL & VL & H & M & 0 & L \\ M & VH & H & H & VL & L & H & M & VL & 0 \end{bmatrix}$$

Step 2: Prepare the maximum weightage of the matrix using the Linguistic table.

Matrix 1.2: Average Matrix Tr(M)

$$\begin{bmatrix} 0 & (0.50) & (0.75) & (0.92) & (0.08) & (0.50) & (0.75) & (0.25) & (0.50) & (0.75) \\ (0.50) & 0 & (0.75) & (0.92) & (0.25) & (0.08) & (0.50) & (0.75) & (0.25) & (0.50) \\ (0.25) & (0.75) & 0 & (0.92) & (0.25) & (0.25) & (0.50) & (0.08) & (0.08) & (0.25) \\ (0.08) & (0.92) & (0.75) & 0 & (0.50) & (0.25) & (0.75) & (0.75) & (0.25) & (0.75) \\ (0.25) & (0.92) & (0.50) & (0.75) & 0 & (0.08) & (0.75) & (0.50) & (0.25) & (0.25) \\ (0.50) & (0.75) & (0.75) & (0.92) & (0.50) & 0 & (0.75) & (0.50) & (0.08) & (0.25) \\ (0.50) & (0.75) & (0.75) & (0.92) & (0.25) & (0.50) & 0 & (0.75) & (0.08) & (0.25) \\ (0.25) & (0.92) & (0.25) & (0.75) & (0.08) & (0.25) & (0.25) & 0 & (0.50) & (0.25) \\ (0.25) & (0.75) & (0.50) & (0.92) & (0.08) & (0.08) & (0.75) & (0.50) & 0 & (0.25) \\ (0.50) & (0.92) & (0.75) & (0.75) & (0.08) & (0.25) & (0.75) & (0.50) & (0.08) & 0 \end{bmatrix}$$

Step 3: Find the limit cycle.

Case (i): Let the tea contain antioxidants is ON state.

(i.e.) TrC_1 is ON state and other nodes in OFF state.

Let $A^{(1)} = (1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0)$

$A^{(1)}Tr(M)_{weight} = \{0, (0.25, 0.50, 0.75), (0.50, 0.75, 1), (0.75, 1, 1), \ (0, 0, 0.25), (0.25, 0.50, 0.75), (0.50, 0.75, 1), (0.\ 0.25, 0.50), (0.25, 0.50, 0.75), (0.50, 0.75, 1)\}$

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$A^{(1)}Tr(M)_{average} = (0, 0.50, 0.75, 0.92, 0.08, 0.50, 0.75, 0.25, 0.50, 0.75)$

$A^{(1)}Tr(M)_{max.weight} = (0, 0, 0, 1, 0, 0, 0, 0, 0, 0) = A_1^{(1)}$

$A_1^{(1)}Tr(\mathrm{M})_{\mathrm{weight}} = \{(0, 0, 0.25), (0.75, 1, 1), (0.50, 0.75, 1), 0,$
$(0.25, 0.50, 0.75), (0, 0.25, 0.50), (0.50, 0.75, 1), (0.50, 0.75, 1), (0, 0.25, 0.50), (0.50, 0.75, 1)\}$

$A_1^{(1)}Tr(M)_{average} = (0.08, 0.92, 0.75, 0, 0.50, 0.25, 0.75, 0.75, 0.25, 0.75)$

$A_1^{(1)}Tr(M)_{max.weight} = (0, 1, 0, 0, 0, 0, 0, 0, 0, 0) = A_2{}^{(1)}$

$A_2^{(1)}Tr(M)_{weight} = \{(0.25, 0.50, 0.75), 0, (0.50, 0.75, 1), (0.75, 1, 1), (0, 0.25, 0.50), (0, 0, 0.25), (0.25, 0.50, 0.75), (0.50, 0.75, 1),$
$(0, 0.25, 0.50), (0.25, 0.50, 0.75)\}$

$A_2^{(1)}Tr(M)_{average} = (0.50, 0, 0.75, 0.92, 0.25, 0.08, 0.50, 0.75, 0.25, 0.50)$

$A_2^{(1)}Tr(M)_{max.weight} = (0, 0, 0, 1, 0, 0, 0, 0, 0, 0) = A_3^{(1)}$

$$\therefore A_3^{(1)} = A_1^{(1)}$$

Do the process for all remaining attributes.

Table 1.2: Total Weightage of the attributes

ON state	T_rC_1	T_rC_2	T_rC_3	T_rC_4	T_rC_5	T_rC_6	T_rC_7	T_rC_8	T_rC_9	T_rC_{10}
1	0.50	0	0.75	0.92	0.25	0.08	0.50	0.75	0.25	0.50
2	0.50	0	0.75	0.92	0.25	0.08	0.50	0.75	0.25	0.50
3	0.50	0	0.75	0.92	0.25	0.08	0.50	0.75	0.25	0.50
4	0.08	0.92	0.75	0	0.50	0.25	0.75	0.75	0.25	0.75
5	0.08	0.92	0.75	0	0.50	0.25	0.75	0.75	0.25	0.75
6	0.50	0	0.75	0.92	0.25	0.08	0.50	0.75	0.25	0.50
7	0.50	0	0.75	0.92	0.25	0.08	0.50	0.75	0.25	0.50
8	0.08	0.92	0.75	0	0.50	0.25	0.75	0.75	0.25	0.75
9	0.50	0	0.75	0.92	0.25	0.08	0.50	0.75	0.25	0.50
10	0.08	0.92	0.75	0	0.50	0.25	0.75	0.75	0.25	0.75
Weight	3.32	3.68	7.5	5.52	3.5	1.48	6	7.5	2.5	6
Average	0.33	0.36	0.75	0.55	0.35	0.14	0.6	0.75	0.25	0.6
Rank	VI	IV	I	III	V	VIII	II	I	VII	II

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5.4 RESULTS

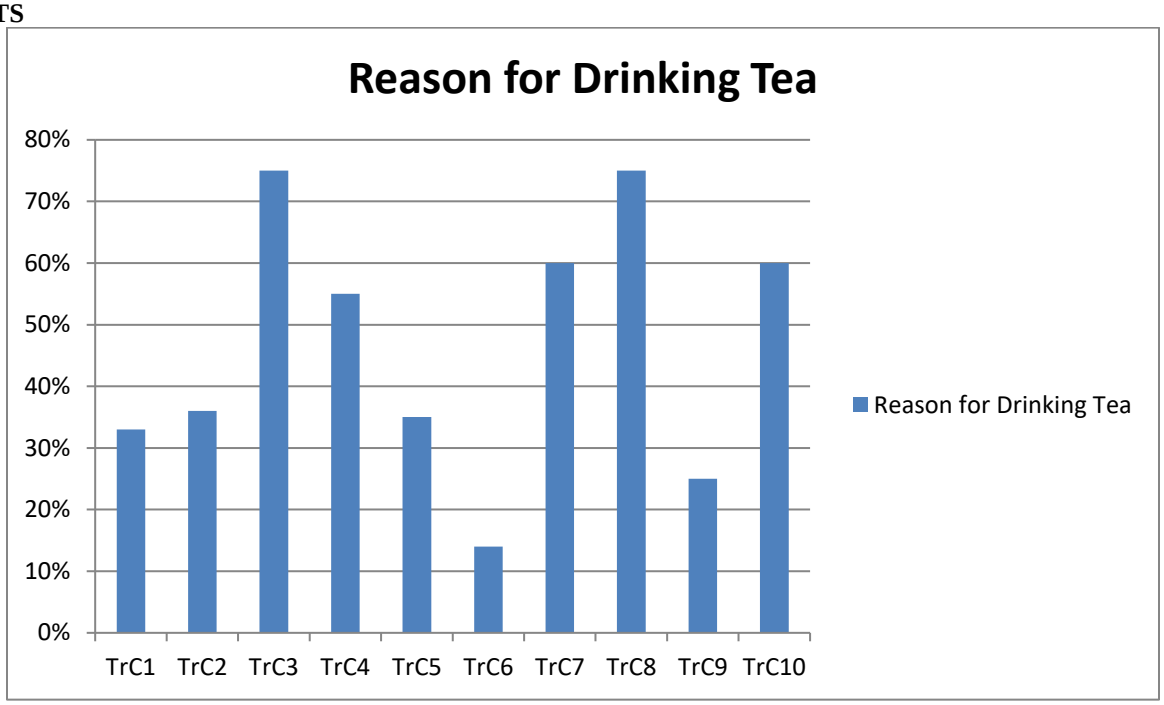


Figure1.2: Column-Chart for Ranking of TrFCM

From the above table, the ranking for the major Reason for Drinking Tea as follows:

RANK I – Boosts energy (75%) and Boosts brain health (75%), RANK III – Herbal tea may help the digestive system (60%) and Tradition and habit (60%), RANK V – Reduce headache (55%), RANK VI – Streesless (36%), RANK VII – Weightloss (35%), RANK VIII – Tea contains antioxidants (33%), RANK IX – Skin saver (25%), RANK X – Tea may reduce the risk of cancer (14%).

6. CONCLUSION

The popularity of tea is a reflection of its numerous benefits, with boosting energy and brain health being two of the most significant reasons. As the world continues to evolve and become increasingly complex, the simple and natural benefits of tea make it an essential part of a healthy and balanced lifestyle.

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