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Fuzzy Knowledge Technique to Predict Weather Condition

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Abstract: This work describes the use of Fuzzy knowledge rule base technique to predict the objects contained in atmospheric temperature and wind speed. Fuzzy Petri nets are used for classification of data with linguistic variables.
Keywords: Transformation,Temperature,Windspeed

I. INTRODUCTION

Back ground of this study is to predict tempertature taking temperature and windspeed into consideration which are the main factors in predicting weather forecast. a temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes the most rapidly around a particular location. greater temperature difference results in increase in wind speed wind speed redistributes energy around

II. PETRI NETS

A Petri net is a graphical representation of a mathematical modeling. A Petri net is a collection of positions and transformations. Positions hold tokens which moves among the positions within the system. Arcs connect positions and transformation
In order to transformation occur all the input positions should have at least one token in it. As transformation is performed one token is removed from all input positions and one token is added to all its output positions

A. Transformation Rule

In order to transformation occur all the input positions should have at least one token in it. As transformation is performed one token is removed from all input positions and one token is added to all its output position.

B. Definition

A fuzzy Petri net is a tuple N=(P,T,S,I,O,□□□□□□M_0) where

$P=\{p_1, p_2, ...p_n\}$ is a finite collection of positions, $n>0$

$T=\{t_1, t_2, ...t_m\}$ is a finite collection of transformations, $m>0$

$S=\{s_1, s_2, ...s_n\}$ is a finite set of statements

$P\cap T = T\cap S = \varnothing$

$I: T\rightarrow 2^P$ is the input activity

$O: T\rightarrow 2^P$ is the output activity

$\alpha : P\rightarrow S$ is the statement binding functions

$\beta : T\rightarrow [0,1]$ is the degree of truth function

$\gamma : T\rightarrow [0,1]$ is the entry function

$M_0 : P\rightarrow [0,1]$ is the primary label

and 2^P denotes a family of all subsets of the set P.
A transformation t is enabled for labeling M only if

$\min(M(p_{i1}), M(p_{i2}), ...M(p_{ik})) \geq \gamma(t) > 0$ for each $p_{ij}\in I(t),\ j=1,2,........k$

1) *Model 1:* If M is a marking of N enabling transformation t and M' the marking derived from M by the firing transformation t, then for each

$$M'(p) = \begin{cases} 0 \; if \;\; p \in I(t), \\ \max(\min(M(p_{i1}), M(p_{i2}), \ldots\ldots M(p_{ik})) * \beta(t), M(p)) \text{ if } p \in O \\ M(p) \; otherwise \end{cases}$$

In this mode a procedure for computing the marking is as follows

1. Tokens from all input places of the transition t are removed (the first condition from definition)
2. Tokens in all output places of t are modified in the following way: at first the value of minimum min for all input places of t is computed, then the product of the computed minimum for all input places of t and the value of truth degree function is determined and finally a value corresponding to for each is obtained as a result of maximum for the computed product value and the current marking (the second condition from definition)
3. Tokens in the remaining places of net N are not changed (the third condition from definition).

2) *Model 2:* If M is a marking of N enabling transformation t and M' the marking derived from M by the firing transformation t, then for each $p \in P$

$$M'(p) = \begin{cases} \max(\min(M(p_{i1}), M(p_{i2}), \ldots\ldots M(p_{ik})) * \beta(t), M(p)) \text{ if } p \in O(t), \\ M(p) \; otherwise \end{cases}$$

The difference in the definition of a marking presented in Mode 2 concerns input places of the fired transition t. In Mode 1 tokens from all input places of the fired transition t are removed (the first definition condition of Mode 1) whereas in Mode 2 all tokens from input places of the fired transition t are copied (the second definition condition of Mode 2).

III. EXPRESSING DEGREE OF TRUTH FOR TEMPERATURE

$$\begin{array}{cc} temp & \begin{matrix} 5 & 10 & 15 & 20 & 25 \end{matrix} \\ \begin{matrix} VL \\ L \\ N \\ H \\ VH \end{matrix} & \begin{bmatrix} 1 & 1 & .8 & .4 & 0 \\ .8 & 1 & .6 & .4 & 0 \\ 0 & .7 & 1 & .6 & .2 \\ 0 & .2 & .4 & 1 & .8 \\ 0 & 0 & .2 & .4 & 1 \end{bmatrix} \end{array}$$

IV. EXPRESSING DEGREE OF TRUTH FOR WIND SPEED

$$\begin{array}{cc} ws & \begin{matrix} 02 & 04 & 6 & 8 & 10 \end{matrix} \\ \begin{matrix} VL \\ L \\ N \\ H \\ VH \end{matrix} & \begin{bmatrix} 1 & .4 & .2 & 0 & 0 \\ .6 & 1 & .5 & .2 & 0 \\ 0 & .6 & 1 & .4 & .2 \\ 0 & .2 & .5 & 1 & .3 \\ 0 & 0 & .3 & .4 & 1 \end{bmatrix} \end{array}$$

V. DEVELOPMENT OF FUZZY PERTI NETS AGAINST TEMPERATURE AND WIND SPEED

Here we have the collection of positions $P=\{P_1,P_2,P_3,P_4,P_5,P_6\}$, the collection of transformations $T=\{t_1,t_2,t_3\}$, the input activity I and the output activity O in the form : $I(t_1)=\{P_1,P_2,P_3\}$, $I(t_2)=\{P_1,P_2,P_3\}$, $I(t_3)=\{P_1,P_2,P_3\}$, $O(t_1)=\{P_4\}$, $O(t_2)=\{P_5\}$, $O(t_3)=\{P_6\}$, the degree of truth function β : $\beta(t_1)=1$, $\beta(t_2)=0.4$, $\beta(t_3)=0.2$, the entry function γ : $\gamma(t_1)=0.4$, $\gamma(t_2)=0.3$, $\gamma(t_3)=0.2$, the primary label $M_0=(1,1,0.8,0.4,0)$

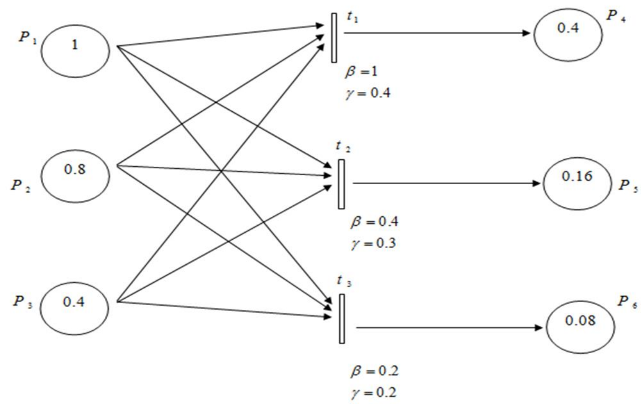

Fig 4.41(a) the markings after firing t_1, t_2, t_3 where all transitions are enabled

Interactional matrix between μ_{tempVL} and $\mu_{windspeedVL}$:

$$\begin{array}{c|ccccc} temp \backslash ws & 1 & 0.4 & 0.2 & 0 & 0 \end{array}$$

$$\mu_{VL\_VL} = \begin{array}{c} 1 \\ 1 \\ 0.8 \\ 0.4 \\ 0 \end{array} \begin{bmatrix} .4 & .16 & .08 & 0 & 0 \\ .4 & .16 & .08 & 0 & 0 \\ .4 & .16 & .08 & 0 & 0 \\ .4 & .16 & .08 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

A. Development Of Fuzzy Perti Nets Against Wind Speed And Temperature

Here we have the collection of positions $Q=\{Q_1,Q_2,Q_3,Q_4,Q_5,Q_6\}$, the collection of transformations $T=\{t_1,t_2,t_3\}$, the input activity I and the output activity O in the form : $I(t_1)=\{Q_1,Q_2,Q_3\}$, $I(t_2)=\{Q_1,Q_2,Q_3\}$, $I(t_3)=\{Q_1,Q_2,Q_3\}$, $O(t_1)=\{Q_4\}$, $O(t_2)=\{Q_5\}$, $O(t_3)=\{Q_6\}$, the degree of truth function β : $\beta(t_1)=1$, $\beta(t_2)=0.8$, $\beta(t_3)=0.4$, the entry function γ : $\gamma(t_1)=0.2$, $\gamma(t_2)=0.2$, $\gamma(t_3)=0.2$, the primary label $M_0=(1,0.4,0.2,0,0)$

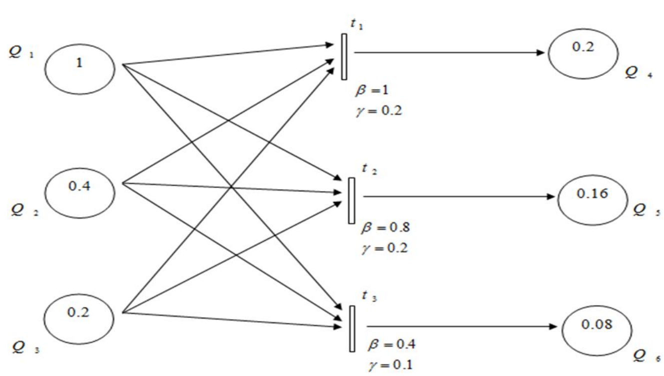

Fig 4.51(a) the markings after firing t_1, t_2, t_3 where all transitions are enabled

Interactional matrix between $\mu_{windspeedVL}$ and μ_{tempVL} :

$$\mu_{VL\_VL} = \begin{array}{c|ccccc} ws \backslash temp & 1 & 1 & 0.8 & 0.4 & 0 \\ \hline 1 & .2 & .2 & .16 & .08 & 0 \\ 0.4 & .2 & .2 & .16 & .08 & 0 \\ 0.2 & .2 & .2 & .16 & .08 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{array}$$

VI. FUZZY KNOWLEDGE RULE BASE FOR FORECAST OF WIND SPEED

Fuzzy knowledge rule base using fuzzy Petri nets is applied here to forecast wind speed. Truth degree is found here for temperature and wind speed for a given temperature

$$\mu_{VL} = [0.1 \quad 0.1 \quad 0.1 \quad 0.1 \quad 0.1]$$
$$\mu_{L} = [0.2 \quad 0.2 \quad 0.2 \quad 0.2 \quad 0.2]$$
$$\mu_{N} = [0.5 \quad 0.5 \quad 0.5 \quad 0.5 \quad 0.5]$$
$$\mu_{H} = [0.8 \quad 0.8 \quad 0.8 \quad 0.8 \quad 0.8]$$
$$\mu_{VH} = [1 \quad 1 \quad 1 \quad 1 \quad 1]$$

Max-product composition is applied to determine composition function

VERY LOW wind speed composition function is determined as

$$WS_{VL} = \mu_{VL} \circ \mu_{VL\_VL} \Rightarrow [0.04 \quad 0.016 \quad 0.008 \quad 0 \quad 0]$$
$$WS_{VL} = \mu_{L} \circ \mu_{L\_VL} \Rightarrow [0.08 \quad 0.032 \quad 0.016 \quad 0 \quad 0]$$
$$WS_{VL} = \mu_{N} \circ \mu_{N\_VL} \Rightarrow [0.1 \quad 0.04 \quad 0.02 \quad 0 \quad 0]$$
$$WS_{VL} = \mu_{H} \circ \mu_{H\_VL} \Rightarrow [0.16 \quad 0.064 \quad 0.032 \quad 0 \quad 0]$$
$$WS_{VL} = \mu_{VH} \circ \mu_{VH\_VL} \Rightarrow [0.2 \quad 0.08 \quad 0.04 \quad 0 \quad 0]$$

LOW wind speed composition function is determined as

$$WS_{L} = \mu_{VL} \circ \mu_{VL\_L} \Rightarrow [0.024 \quad 0.04 \quad 0.02 \quad 0.008 \quad 0]$$
$$WS_{L} = \mu_{L} \circ \mu_{L\_L} \Rightarrow [0.048 \quad 0.08 \quad 0.04 \quad 0.016 \quad 0]$$
$$WS_{L} = \mu_{N} \circ \mu_{N\_L} \Rightarrow [0.06 \quad 0.1 \quad 0.05 \quad 0.02 \quad 0]$$
$$WS_{L} = \mu_{H} \circ \mu_{H\_L} \Rightarrow [0.096 \quad 0.16 \quad 0.08 \quad 0.032 \quad 0]$$
$$WS_{L} = \mu_{VH} \circ \mu_{VH\_L} \Rightarrow [0.12 \quad 0.2 \quad 0.1 \quad 0.04 \quad 0]$$

NORMAL wind speed composition function is determined as

$$WS_{N} = \mu_{VL} \circ \mu_{VL\_N} \Rightarrow [0 \quad 0.024 \quad 0.04 \quad 0.016 \quad 0.008]$$
$$WS_{N} = \mu_{L} \circ \mu_{L\_N} \Rightarrow [0 \quad 0.048 \quad 0.08 \quad 0.032 \quad 0.016]$$
$$WS_{N} = \mu_{N} \circ \mu_{N\_N} \Rightarrow [0 \quad 0.06 \quad 0.1 \quad 0.04 \quad 0.02]$$
$$WS_{N} = \mu_{H} \circ \mu_{H\_N} \Rightarrow [0 \quad 0.096 \quad 0.16 \quad 0.064 \quad 0.032]$$
$$WS_{N} = \mu_{VH} \circ \mu_{VH\_N} \Rightarrow [0 \quad 0.12 \quad 0.2 \quad 0.08 \quad 0.04]$$

HIGH wind speed composition function is determined as

$$WS_{H} = \mu_{VL} \circ \mu_{VL\_H} \Rightarrow [0 \quad 0.008 \quad 0.02 \quad 0.04 \quad 0.012]$$
$$WS_{H} = \mu_{L} \circ \mu_{L\_H} \Rightarrow [0 \quad 0.016 \quad 0.04 \quad 0.08 \quad 0.024]$$
$$WS_{H} = \mu_{N} \circ \mu_{N\_H} \Rightarrow [0 \quad 0.02 \quad 0.05 \quad 0.1 \quad 0.03]$$
$$WS_{H} = \mu_{H} \circ \mu_{H\_H} \Rightarrow [0 \quad 0.032 \quad 0.08 \quad 0.16 \quad 0.048]$$
$$WS_{H} = \mu_{VH} \circ \mu_{VH\_H} \Rightarrow [0 \quad 0.04 \quad 0.1 \quad 0.2 \quad 0.06]$$

VERY HIGH wind speed composition function is determined as

$$WS_{VH} = \mu_{VL} \circ \mu_{VL\_VH} \Rightarrow [0 \quad 0 \quad 0.012 \quad 0.016 \quad 0.04]$$

$$WS_{VH} = \mu_{L} \circ \mu_{L\_VH} \Rightarrow [0 \quad 0 \quad 0.024 \quad 0.032 \quad 0.08]$$

$$WS_{VH} = \mu_{N} \circ \mu_{N\_VH} \Rightarrow [0 \quad 0 \quad 0.03 \quad 0.04 \quad 0.1]$$

$$WS_{VH} = \mu_{H} \circ \mu_{H\_VH} \Rightarrow [0 \quad 0 \quad 0.048 \quad 0.064 \quad 0.16]$$

$$WS_{VH} = \mu_{VH} \circ \mu_{VH\_VH} \Rightarrow [0 \quad 0 \quad 0.06 \quad 0.08 \quad 0.2]$$

VII. DEFUZZIFICATION OF TEMPERATURE AND WIND SPEED

Here we conclude the expression of temperature and wind speed using Defuzzification

$$TEMP = \frac{\forall_i \sum x_i \mu(x_i)}{\forall_i \sum \mu(x_i)}$$

$$x_i = [5 \quad 10 \quad 15 \quad 20 \quad 25]$$

Table (a) shows below defuzzified values of Temperature

TEMPERATURE			
S.NO	LINGUISTIC VARIABLE	DEGREE OF TRUTH $\mu(x_i)$	TEMP (V_k)
1	Very Low	$[0.02 \quad 0.02 \quad 0.016 \quad 0.008 \quad 0]$	10.9375
2	Very Low	$[0.04 \quad 0.04 \quad 0.032 \quad 0.016 \quad 0]$	10.9375
3	Very Low	$[0.1 \quad 0.1 \quad 0.08 \quad 0.04 \quad 0]$	10.9375
4	Very Low	$[0.16 \quad 0.16 \quad 0.128 \quad 0.064 \quad 0]$	10.9375
5	Very Low	$[0.3 \quad 0.3 \quad 0.24 \quad 0.12 \quad 0]$	10.9375
6	Low	$[0.016 \quad 0.02 \quad 0.012 \quad 0.008 \quad 0]$	11.0714
7	Low	$[0.032 \quad 0.04 \quad 0.024 \quad 0.016 \quad 0]$	11.0714
8	Low	$[0.08 \quad 0.1 \quad 0.06 \quad 0.04 \quad 0]$	11.0714
9	Low	$[0.128 \quad 0.16 \quad 0.096 \quad 0.064 \quad 0]$	11.0714
10	Low	$[0.24 \quad 0.3 \quad 0.18 \quad 0.12 \quad 0]$	11.0714
11	Normal	$[0 \quad 0.014 \quad 0.02 \quad 0.012 \quad 0.004]$	15.6
12	Normal	$[0 \quad 0.028 \quad 0.04 \quad 0.024 \quad 0.008]$	15.6
13	Normal	$[0 \quad 0.07 \quad 0.1 \quad 0.06 \quad 0.02]$	15.6
14	Normal	$[0 \quad 0.112 \quad 0.16 \quad 0.096 \quad 0.032]$	15.6
15	Normal	$[0 \quad 0.21 \quad 0.3 \quad 0.18 \quad 0.06]$	15.6
16	High	$[0 \quad 0.004 \quad 0.008 \quad 0.02 \quad 0.016]$	20
17	High	$[0 \quad 0.008 \quad 0.016 \quad 0.04 \quad 0.032]$	20
18	High	$[0 \quad 0.02 \quad 0.04 \quad 0.1 \quad 0.08]$	20
19	High	$[0 \quad 0.032 \quad 0.064 \quad 0.16 \quad 0.128]$	20
20	High	$[0 \quad 0.06 \quad 0.12 \quad 0.3 \quad 0.24]$	20
21	Very High	$[0 \quad 0 \quad 0.004 \quad 0.008 \quad 0.02]$	22.5
22	Very High	$[0 \quad 0 \quad 0.008 \quad 0.016 \quad 0.04]$	22.5
23	Very High	$[0 \quad 0 \quad 0.02 \quad 0.04 \quad 0.1]$	22.5
24	Very High	$[0 \quad 0 \quad 0.032 \quad 0.064 \quad 0.16]$	22.5
25	Very High	$[0 \quad 0 \quad 0.06 \quad 0.12 \quad 0.3]$	22.5

$$WS = \frac{\forall_i \sum x_i \mu(x_i)}{\forall_i \sum \mu(x_i)}$$

$$x_i = [2 \quad 4 \quad 6 \quad 8 \quad 10]$$

Table (b) below shows defuzzified values of Wind speed

WIND SPEED (WS)			
S.NO	LINGUISTIC VARIABLE	DEGREE OF TRUTH $\mu(x_i)$	WIND SPEED (V_k)
1	Very Low	$[0.04 \quad 0.016 \quad 0.008 \quad 0 \quad 0]$	3
2	Very Low	$[0.08 \quad 0.032 \quad 0.016 \quad 0 \quad 0]$	3
3	Very Low	$[0.1 \quad 0.04 \quad 0.02 \quad 0 \quad 0]$	3
4	Very Low	$[0.16 \quad 0.064 \quad 0.032 \quad 0 \quad 0]$	3
5	Very Low	$[0.2 \quad 0.08 \quad 0.04 \quad 0 \quad 0]$	3
6	Low	$[0.024 \quad 0.04 \quad 0.02 \quad 0.008 \quad 0]$	4.2608
7	Low	$[0.048 \quad 0.08 \quad 0.04 \quad 0.016 \quad 0]$	4.2608
8	Low	$[0.06 \quad 0.1 \quad 0.05 \quad 0.02 \quad 0]$	4.2608
9	Low	$[0.096 \quad 0.16 \quad 0.08 \quad 0.032 \quad 0]$	4.2608
10	Low	$[0.12 \quad 0.2 \quad 0.1 \quad 0.04 \quad 0]$	4.2608
11	Normal	$[0 \quad 0.024 \quad 0.04 \quad 0.016 \quad 0.008]$	6.1818
12	Normal	$[0 \quad 0.048 \quad 0.08 \quad 0.032 \quad 0.016]$	6.1818
13	Normal	$[0 \quad 0.06 \quad 0.1 \quad 0.04 \quad 0.02]$	6.1818
14	Normal	$[0 \quad 0.096 \quad 0.16 \quad 0.064 \quad 0.032]$	6.1818
15	Normal	$[0 \quad 0.12 \quad 0.2 \quad 0.08 \quad 0.04]$	6.1818
16	High	$[0 \quad 0.008 \quad 0.02 \quad 0.04 \quad 0.012]$	7.4
17	High	$[0 \quad 0.016 \quad 0.04 \quad 0.08 \quad 0.024]$	7.4
18	High	$[0 \quad 0.02 \quad 0.05 \quad 0.1 \quad 0.03]$	7.4
19	High	$[0 \quad 0.032 \quad 0.08 \quad 0.16 \quad 0.048]$	7.4
20	High	$[0 \quad 0.04 \quad 0.1 \quad 0.2 \quad 0.06]$	7.4
21	Very High	$[0 \quad 0 \quad 0.012 \quad 0.016 \quad 0.04]$	8.8235
22	Very High	$[0 \quad 0 \quad 0.024 \quad 0.032 \quad 0.08]$	8.8235
23	Very High	$[0 \quad 0 \quad 0.03 \quad 0.04 \quad 0.1]$	8.8235
24	Very High	$[0 \quad 0 \quad 0.048 \quad 0.064 \quad 0.16]$	8.8235
25	Very High	$[0 \quad 0 \quad 0.06 \quad 0.08 \quad 0.2]$	8.8235

VIII. CALCULATING QUANTIFIABLE VALUE OF TEMPERATURE

There are several methods for calculating a quantifiable value for fuzzy set but the one to be used in this project is Centroid method.

$$TEMPERATURE = \frac{\sum_{k=1}^{n} \mu(V_k) \times V_k}{\sum_{k=1}^{n} \mu(V_k)}$$

$\mu(V_k)$ is the truth degree value of each variable (Temperature and Wind speed)

V_k is the value of the variable defuzzified

Table (c) below shows the relationship connecting temperature and wind speed

WS TEMP	VL	L	N	H	VH
VL	6.96	6.48	6.97	7.79	9.01
L	8.38	7.66	7.57	8.13	9.19
N	13.5	12.36	10.89	10.55	11.08
H	18.11	16.85	14.68	13.7	13.79
VH	20.72	19.46	17.06	15.78	15.66

IX. CONCLUSION

An attempt to forecast temperature has been done. Statistical methods can be used in forecasting weather. But it has a major drawback that is the percentage of error that occurs. As fuzzy logic inference has a lower percentage of error, here in this research work fuzzified temperature and wind speed values are defuzzified using centroid method and the apparent temperature value is calculated. The final table shows that lower the temperature faster the temperature increases according to increase in wind speed.

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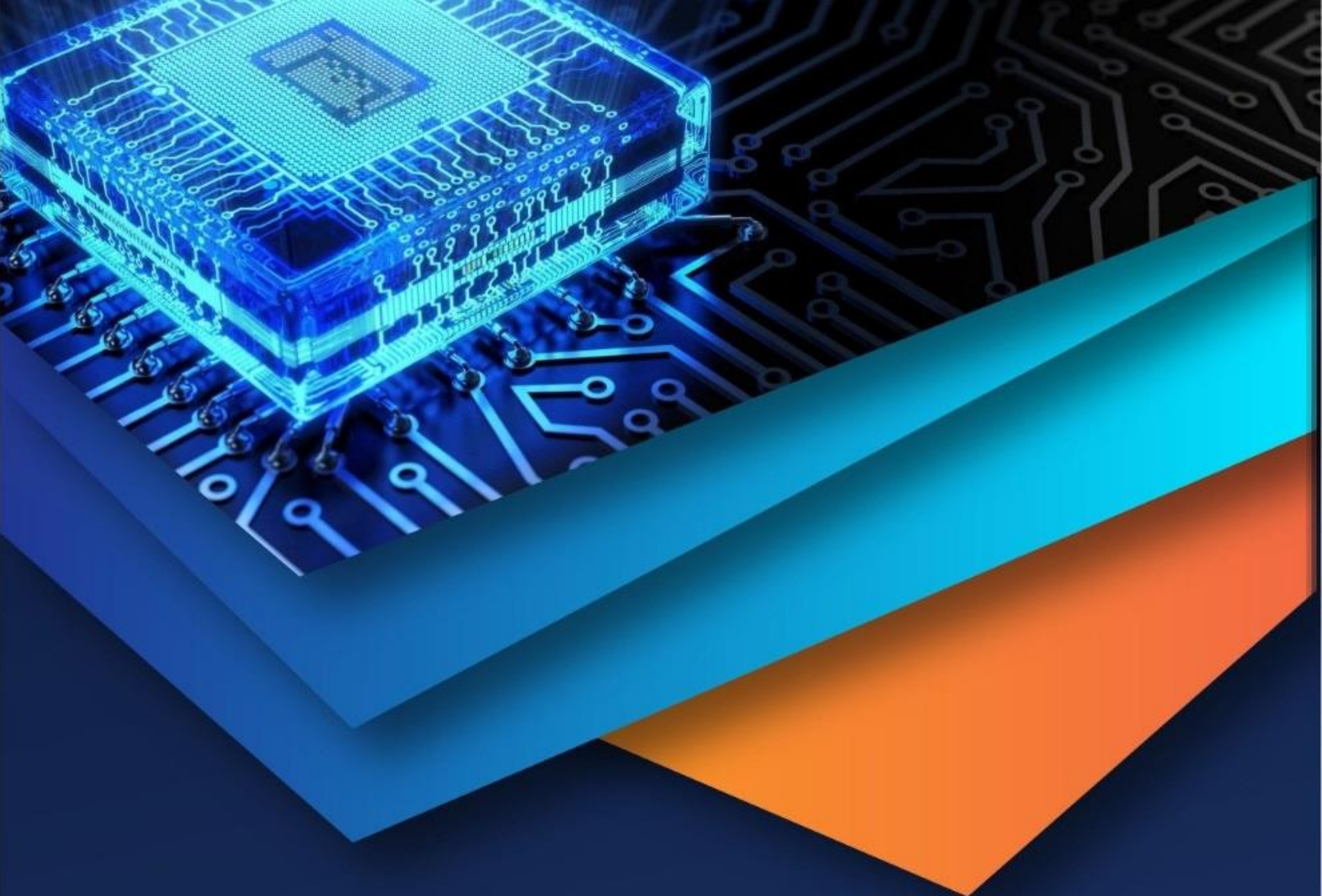

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