

# Fuzzy Analytical Hierarchy Process Based Optimal Work Station node prediction for Large Networks

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**Abstract:** Cloud Computing is an emerging computing technology and delivering lots of services to the end users. In order to ensure the quality of cloud service, the service request ought to be ready to dynamically predict the optimal work station node. The research proposes an optimal work station node prediction in Hierarchical large networks using Fuzzy Analytical Hierarchical Process (AHP). This work is considered as a hierarchical model to explore each level and their sublevel based on the resource availability. The prediction of optimal workstation is dogged on the resource factors: Energy, Memory and Cost. Each work station periodically determines these factors with sub level work stations. The advantage of the proposed work is to predict the best workstation to serve an efficient cloud service for large networks. The proposed model simulated by using MATLAB tool, experiments has been conducted to prove the appropriateness of this novel approach.

**Index Terms:** Cloud computing, Quality of Service, Service analysis, Fuzzy Analytic Hierarchy Process (FAHP).

## I. INTRODUCTION

Several computing paradigms have promised to deliver the utility computing vision and these include cluster computing, Grid computing, and more recently Cloud computing [1]. The utility computing capabilities are deliberated as software and hardware components in the large repository. Cloud computing is a paradigm for utility computing. It is a new era in making varieties of information carried through internet connections by using connective devices [8]. It offers its services in pay and use method for its clients. The Data center is a sophisticated high definition server, which runs applications virtually in cloud computing. It moves the client application, services and data to a centralized large pool called Big Data centers [7]. It enhances flexibility and enables data centers to be dynamic in nature. To provide better cloud service quality, it is essential to dynamically identify information processing of the particular service request. First, we need to supervise the service request data and we can identify whether it happens in a large network service request or not. Second, if the large network service request is produced, the size of the data and the stipulate for the resources and corresponding work station need to be predicted [13]. Existing cloud service prediction approaches were typically focused on cloud computing resource based quantities provided by the

service. In cloud computing scenario, specifically for large networks, the service is not only satisfied with resources but also considered with other constraints. The required work station is far away from the service request. To overcome this issue, this novel work applies Fuzzy Analytical Hierarchical Process (AHP) into a Hierarchical large network mode [14]. One of the most popular analytical techniques for complex decision-making is the Fuzzy Analytic Hierarchy Process (FAHP). Fuzzy AHP was developed by Laarhoven and Pedrycz [10] in the early 1983s. Fuzzy coupled with AHP as a decision method to ambiguity in levying the importance of feature and the performance ratings of alternative with esteem to features. Traditional multiple decision methods do not successfully feel problems with that vague data's.

The fuzzy AHP approach is a logical method for the choice and validation problems that incorporates the idea of fuzzy sets theory [11] and the hierarchical structure analysis. First step, here is rating issue describes many criteria. This criterion is also isolated into sub category. The outcome of fuzzy AHP is a main concern for ranking the overall choices, these alternatives lastly useful decision making to select the best method. The judgment needs to work the vagueness while evaluating the assessments of the choices. For judging these vagueness into believe ration fuzzy numbers are used as a substitute of crisp numbers [12].

FAHP [4, 10] is an extension of AHP. The assessment of different criteria requires the use of fuzzy membership function value. AHP is based on the use of crisp numbers [14]. A fuzzy member function [10] is related to a special fuzzy set  $F = \{(x, \mu_f(x), x \in R\}$ , where  $x$  takes its values on the real line,  $R: -\infty \leq x \leq \infty$  and  $\mu_f(x)$  is a continuous mapping from  $R$  to the closed interval  $[0, 1]$ .

The contribution of paper

- This novel work proposes a cloud service forecast approach based on Fuzzy AHP method, which is used to predict the optimal workstation node in large networks.
- The approach efficiently constructs a hierarchical model to serve better cloud service paradigm for large networks.

## II. SYSTEM MODEL

Figure 1 illustrates the system architecture. In this model, there are fourteen work stations (depicted by a circle). It is a source to many destination scenarios. The environment is considered as large networks mapped into multi-cloud services. Each node represented as a Work Station (WS). Each edge is assigned as a next level work stations. The aim of this proposed architecture is to find optimal WS supporting for the cloud service request. Each work station maintains resource parameters such as Energy, Memory and cost. The method is starting from source WS (WS1) with the specified service request it travels to reach the optimal WS (WS13-Orange coloured arrows) to fully satisfy the service request. In that Figure 1, WS1 is assigned as the root node for the hierarchical architecture. The root WS is periodically updated with sub level Work Stations for their resource availability.

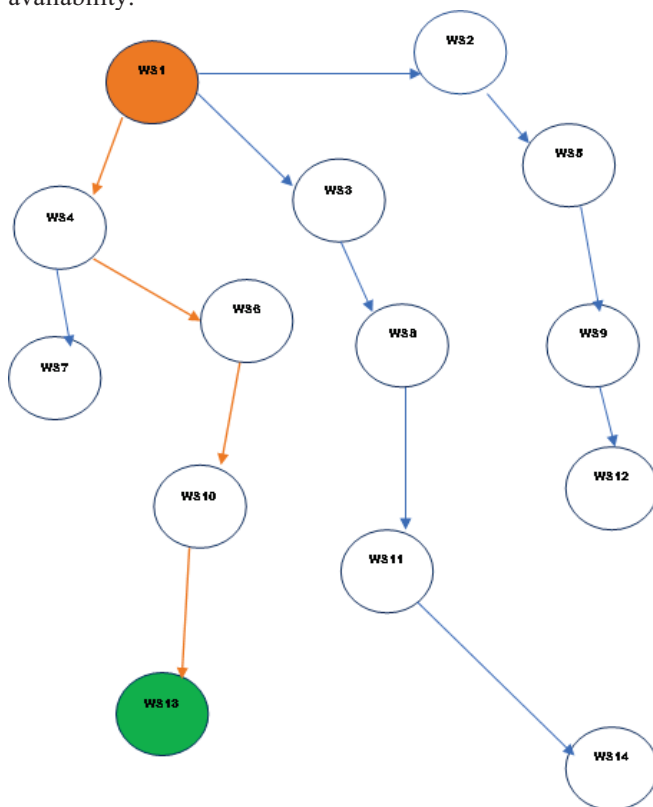


Figure1. Hierarchical Model

## III. PREDICTION OF OPTIMAL WORK STATION USING FUZZY AHP(FAHP)

### A. Step 1: Fuzzification

In this first step, the linguistic terms, criteria their quantifications are tabulated in Table3. Here, it is assumed more than one alternative and criteria. Because the limited number of factors are influencing for finding the best optimal path [5, 6]. Here, 3 –point scale is used to convert the fuzzy linguistic terms into crisp numbers. Table 2 shows the crisp data for corresponding fuzzy linguistic terms and matrix is known as Decision Making Matrix (DMM).

### Fuzzy System:

NumInputs=3NumOutputs=1NumRules=29  
 AndMethod='min'OrMethod='max'  
 ImpMethod='min'AggMethod='max'

DefuzzMethod='centroid'

Fuzzy trapezoid view of inputs Energy membership functions is defined in Equations (1)-(3).

[Input1]='Energy'Range=[0 1]NumMFs=3

MF1='Low':'trapmf', is defined in Equation (1)

$$\mu_{Low} = \begin{cases} 1 & \text{if } 0 \leq x \leq 0.201 \\ \frac{0.39921-x}{0.19821} & \text{if } 0.201 \leq x \leq 0.39921 \\ 0 & \text{Otherwise} \end{cases} \quad (1)$$

MF2='Medium':'trapmf', is defined in Equation (2)

$$\mu_{Medium} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.198 \\ \frac{x-0.198}{0.203} & \text{if } 0.198 \leq x \leq 0.401 \\ 1 & \text{if } 0.401 \leq x \leq 0.6 \\ \frac{0.8-x}{0.2} & \text{if } 0.6 \leq x \leq 0.8 \\ 0 & \text{Otherwise} \end{cases} \quad (2)$$

MF3='High':'trapmf', is defined in Equation (3)

$$\mu_{High} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.6 \\ \frac{0.8-x}{0.2} & \text{if } 0.6 \leq x \leq 0.8 \\ 1 & \text{Otherwise} \end{cases} \quad (3)$$

Fuzzy trapezoid view of inputs MemConsumption membership functions is defined in Equations (4)-(6).

[Input2]='MemConsumption'Range=[0 1]  
 NumMFs=3

MF1='Small':'trapmf', is defined in Equation (4)

$$\mu_{Small} = \begin{cases} 1 & \text{if } 0 \leq x \leq 0.199 \\ \frac{0.4967-x}{0.2977} & \text{if } 0.199 \leq x \leq 0.4967 \\ 0 & \text{Otherwise} \end{cases} \quad (4)$$

MF2='Medium':'trapmf', is defined in Equation (5)

$$\mu_{Medium} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.1468 \\ \frac{x-0.1468}{0.3132} & \text{if } 0.1468 \leq x \leq 0.46 \\ 1 & \text{if } 0.46 \leq x \leq 0.54 \\ \frac{0.85-x}{0.31} & \text{if } 0.54 \leq x \leq 0.85 \\ 0 & \text{Otherwise} \end{cases} \quad (5)$$

MF3='Large':'trapmf', is defined in Equation (6)

$$\mu_{Large} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.4989 \\ \frac{0.803-x}{0.3041} & \text{if } 0.4989 \leq x \leq 0.803 \\ 1 & \text{Otherwise} \end{cases} \quad (6)$$

Fuzzy trapezoid view of inputsCost membership functions is defined in Equations (7)-(9).

[Input3]='Cost'Range=[0 1]NumMFs=3  
MF1='Minimum':'trapmf',is defined in Equation (7)

$$\mu_{Minimum} = \begin{cases} 1 & \text{if } 0 \leq x \leq 0.303 \\ \frac{0.3505-x}{0.0475} & \text{if } 0.303 \leq x \leq 0.3505 \\ 0 & \text{Otherwise} \end{cases} \quad (7)$$

MF2='Moderate':'trapmf',is defined in Equation (8)

$$\mu_{Moderate} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.151 \\ \frac{x-0.151}{0.25} & \text{if } 0.151 \leq x \leq 0.401 \\ 1 & \text{if } 0.401 \leq x \leq 0.601 \\ \frac{0.8532-x}{0.2522} & \text{if } 0.601 \leq x \leq 0.8532 \\ 0 & \text{Otherwise} \end{cases} \quad (8)$$

MF3='Maximum':'trapmf',is defined in Equation (9)

$$\mu_{Maximum} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.652 \\ \frac{0.7037-x}{0.0517} & \text{if } 0.652 \leq x \leq 0.7037 \\ 1 & \text{Otherwise} \end{cases} \quad (9)$$

Fuzzy trapezoid view of output 'OptimalNeighbourNode' membership functions is defined in Equations (10)-(12).

[Output1]='OptimalNeighbourNode'Range=[0 1]NumMFs=3

MF1='Poor':'trapmf',is defined in Equation (10)

$$\mu_{Poor} = \begin{cases} 1 & \text{if } 0 \leq x \leq 0.206 \\ \frac{0.3028-x}{0.0968} & \text{if } 0.206 \leq x \leq 0.3028 \\ 0 & \text{Otherwise} \end{cases} \quad (10)$$

MF2='Fair':'trapmf',is defined in Equation (11)

$$\mu_{Fair} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.14 \\ \frac{x-0.14}{0.16} & \text{if } 0.14 \leq x \leq 0.3 \\ 1 & \text{if } 0.3 \leq x \leq 0.501 \\ \frac{0.6582-x}{0.1572} & \text{if } 0.501 \leq x \leq 0.6582 \\ 0 & \text{Otherwise} \end{cases} \quad (11)$$

MF3='Good':'trapmf',is defined in Equation (12)

$$\mu_{Good} = \begin{cases} 0 & \text{if } 0 \leq x \leq 0.5444 \\ \frac{0.696-x}{0.1516} & \text{if } 0.5444 \leq x \leq 0.696 \\ 1 & \text{Otherwise} \end{cases} \quad (12)$$

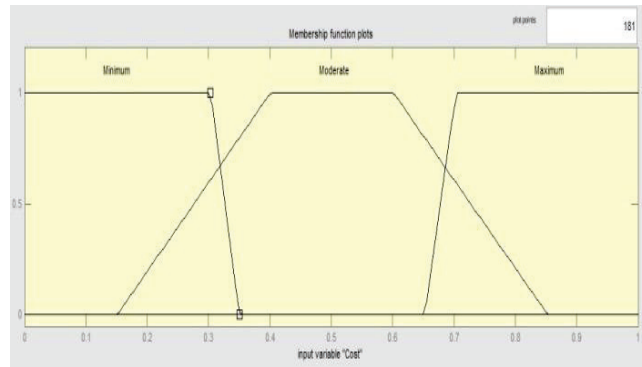


Figure 2. Fuzzy trapezoid membership function for Cost

Figure 2 shows the fuzzification parameter –Cost with three fuzzy sets: Minimum- Moderate- Maximum and their corresponding membership functions.

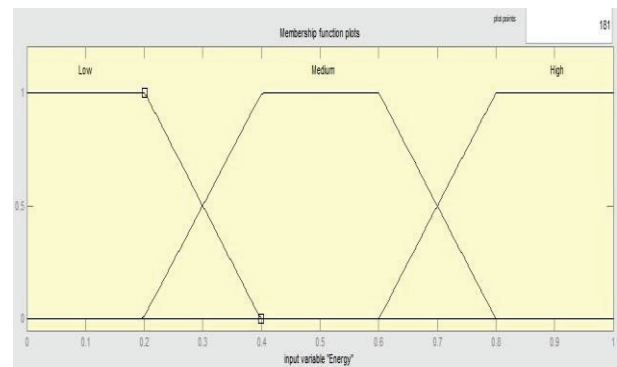


Figure 3. Fuzzy trapezoid membership function for Energy

Figure 3 shows the fuzzification parameter –Energy with three fuzzy sets: Low- Medium- High and their corresponding membership functions.

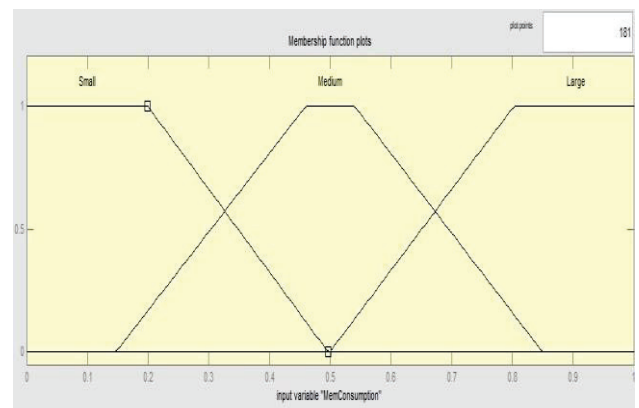


Figure 4. Fuzzy trapezoid membership function for Memory

Figure 4 shows the fuzzification parameter –Memory with three fuzzy sets: Small - Medium- Large and their corresponding membership functions.

The Table I displays the fuzzy values of neighbours of WS1 are WS2, WS 3 and WS 4 and the criteria Energy, memory and cost.

TABLE I.  
FUZZY QUANTIFICATION NUMBER FOR CRISP VALUE

Neighbour Node	Energy	Memory	Cost
WS 2	0.85	0.3251	1
WS 4	0.76	1	0.6443
WS 3	0.01	0.1452	1

TABLE II.  
DECISION MAKING MATRIX FOR WORK STATION RANKING

Neighbour Node	Fuzzy Score	Crisp Ranking
WS 2	0.725	2
WS 4	0.801	1
WS 3	0.385	3

TABLE III.  
FUZZY AHP QUANTIFICATION OF CRITERIA AND ALTERNATIVES

Fuzzy Range	Energy level of neighbours nodes	Consumption of memory	Cost of the path
FR1	Low	Small	Minimum
FR2	Medium	Medium	Moderate
FR3	High	Large	Maximum

*B. Step 2 Consistency checking*

It is used to check, and whether the allocating weights are based on the rule reasoning or not, regularly this value is less than 0.1. It implies the weights are reliable [2, 3].

A relative significant matrix to allocate weights for contrasting criteria with criteria is shown below, the matrix produced with diagonal elements are always zero. The criteria mapped with same to be one.  $P_{ij}=P_{ji}$  where P is a factor of matrix

	E	M	C
Energy	1	10	7
Memory	$\frac{1}{10}$	1	$\frac{1}{5}$
Cost	$\frac{1}{7}$	5	1

By applying these values, it finds Geometric Mean (GM) is

$$GM_1 = (1 \cdot 10 \cdot 7)^{1/3} = 4.1213$$

$$GM_2 = (1/10 \cdot 1 \cdot 1/5)^{1/3} = 0.2714$$

$$GM_3 = (1/7 \cdot 5 \cdot 1)^{1/3} = 0.8939$$

So, Total Geometric mean (GM) =  $GM_1 + GM_2 + GM_3 = 5.2866$

*C. Step 3: Prediction of normalized weights*

$$Weight_1 = 4.1213 / 5.2866 = 0.7796,$$

$$Weight_2 = 0.2714 / 5.2866 = 0.0513 \text{ and}$$

$$Weight_3 = 0.8939 / 5.2866 = 0.1690$$

Consistency can now be checked using following formula:

$$P_3 = (P_1 \times P_2) \tag{13}$$

Where P1 is relative importance matrix and P2 is weigh matrix obtained from equation (13).

$$P_3 = \begin{bmatrix} 1 & 10 & 7 \\ 1/10 & 1 & 1/5 \\ 1/7 & 5 & 1 \end{bmatrix} * \begin{bmatrix} 0.779 \\ 0.051 \\ 0.169 \end{bmatrix} = \begin{bmatrix} 2.47 \\ 0.16 \\ 0.53 \end{bmatrix}$$

Further,

$$P_4 = P_3 / P_2$$

$$\begin{bmatrix} 2.47 \\ 0.16 \\ 0.53 \end{bmatrix} / \begin{bmatrix} 0.779 \\ 0.051 \\ 0.169 \end{bmatrix} = \begin{bmatrix} 3.17 \\ 3.13 \\ 3.14 \end{bmatrix}$$

Finding Average of P4 i.e  $\lambda_{max} = (3.17 + 3.13 + 3.14) / 3 = 3.144$

Then Calculating Consistency Index (CI)

$$I = (\lambda_{max} - n) / (n - 1)$$

n is a size of matrix,

$$= (3.144 - 3) / 2$$

$$CI = 0.072.$$

Consistency Ratio (CR) =  $CI / RI$

$$= 0.072 / 0.82$$

$$= 0.0878$$

$$0.0878 < 0.1$$

Here Random index already mentioned for particular collection of criteria, the value is 0.82. Hence, value of CR is less than 0.1, so the weights are reliable.

*D. Step 4: Pair wise comparison*

Pair wise assessment of alternative to alternative is achieved for each criterion as below:

	WS2	WS3	WS4
WS2			
WS3	1	0.801	0.385
WS4	$1/0.801$	1	0.385
WS4	$1/0.385$	$1/0.385$	1

By applying these values, it finds Geometric Mean (GM) is

$$GM_1 = (1 \cdot 0.801 \cdot 0.385)^{1/3} = 0.675$$

$$GM_2 = (1/0.801 \cdot 1 \cdot 0.385)^{1/3} = 0.783$$

$$GM_3 = (0.385 \cdot 1/0.385 \cdot 1)^{1/3} = 0.998$$

So, Total Geometric mean (GM) =  
 $GM_1 + GM_2 + GM_3 = 2.456$

Weight  $_1 = 0.675 / 2.456 = 0.274$ ,  
 Weight  $_2 = 0.783 / 2.456 = 0.318$  and  
 Weight  $_3 = 0.998 / 2.456 = 0.406$

Consistency can now be checked using following formula:

$$P3 = (P1 \times P2) \tag{13}$$

Where P1 is relative importance matrix and P2 is weight matrix obtained from equation (13).

$$P3 = \begin{bmatrix} 1 & 0.801 & 0.385 \\ 1/0.801 & 1 & 0.385 \\ 1/0.385 & 1/0.385 & 1 \end{bmatrix} * \begin{bmatrix} 0.274 \\ 0.318 \\ 0.406 \end{bmatrix} = \begin{bmatrix} 0.684 \\ 0.769 \\ 1.937 \end{bmatrix}$$

Further,

$$P4 = P3 / P2$$

$$\begin{bmatrix} 0.684 \\ 0.769 \\ 1.937 \end{bmatrix} / \begin{bmatrix} 0.274 \\ 0.318 \\ 0.406 \end{bmatrix} = \begin{bmatrix} 2.49 \\ 2.41 \\ 4.77 \end{bmatrix}$$

Finding Average of P4 i.e  
 $\lambda_{max} = (2.49 + 2.41 + 4.77) / 3 = 3.157$

Then Calculating Consistency Index(CI)

$$I = (\lambda_{max} - n) / (n - 1)$$

n is a size of matrix,

$$= (3.157 - 3) / 2$$

$$CI = 0.0785$$

$$\text{Consistency Ratio (CR)} = CI / RI$$

$$= 0.0785 / 0.82$$

$$= 0.0957$$

$$0.0957 < 0.1$$

Hence the weights are consistent.

*E. Step 5: Judgement matrix*

**STEP 5:** A matrix is formed with the help of obtained weights in case of pair-wise comparison matrix for three different criteria as calculated in step 4 is:-

$$\begin{bmatrix} 2.47 & 0.684 & 0.487 \\ 0.16 & 0.769 & 0.538 \\ 0.53 & 1.937 & 0.894 \end{bmatrix}$$

So the final rank can be obtained as below:

$$\begin{bmatrix} 2.47 & 0.684 & 0.487 \\ 0.16 & 0.769 & 0.538 \\ 0.53 & 1.937 & 0.894 \end{bmatrix} \times \begin{bmatrix} 0.274 \\ 0.318 \\ 0.406 \end{bmatrix} = \begin{bmatrix} 1.09 \\ 0.50 \\ 1.25 \end{bmatrix}$$

Deciding the rank according to the higher value of above matrix, hence ranking is WS4, WS 3 and WS 2.

$$\begin{bmatrix} 2.47 & 0.684 & 0.487 \\ 0.16 & 0.769 & 0.538 \\ 0.53 & 1.937 & 0.894 \end{bmatrix}$$

**IV. PROPOSED ALGORITHM**

```

void Prediction_Work station (int G[MAX][MAX], int
M[MAX], int E[MAX], int n, int SN, int FN)
begin
// G-Cost Matrix representation of the nodes of order n x n
// M-Memory Consumption Vector representation of the
nodes of order n x 1
// E- Energy Level Vector representation of the nodes of
order n x 1
// n - Number of nodes in the network
// SN - start node
// FN - final node
// MF1-MF12 - are Fuzzy Trapezoidal Membership
function
int cost[MAX][MAX], distance[MAX], pred[MAX];
int visited[MAX], count, mindistance, nextnode, i, j;

//pred[] stores the predecessor of each node
//count gives the number of nodes seen so far
//create the cost matrix
for i=0 to n-1 do
for j=0 to n-1 do
if(G[i,j]==0)
cost[i,j]=INFINITY;
else
cost[i, j]=G[i,j];

//initialize pred[], distance[] and visited[]
for i=0 to n-1 do begin
distance[i]=cost[SN, i];
pred[i]=SN;
visited[i]=0;
end

distance[SN]=0;
visited[SN]=1;

count=1;

while(count<n-1) do
begin
mindistance=INFINITY;

//nextnode gives the node at minimum distance
for i=0 to n-1 do
if(distance[i]<mindistance&&!visited[i])
begin
mindistance=distance[i];
nextnode=i;
end
    
```



```

//check if a better path exists through
nextnode
visited[nextnode]=1;
for i= 0 to n-1 do begin
    if(!visited[i])
        if(mindistance+cost[nextnode][i]<distance[i] && max(MF10(
            max(MF1(M[nextnode]),
            MF4(E[nextnode]),
            MF7(G[nextnode][i])),
            MF11(max(MF2(M[nextnode]),MF5(E[nextnode]),
            MF8(G[nextnode][i])),
            MF12(max(MF3(M[nextnode]),MF6(E[nextnode]),
            MF9(G[nextnode][i]))))>0.5
        begin
            distance[i]=mindistance+cost[nextnode][i];
            pred[i]=nextnode;
        end
        count++;
    end
//print the path and distance of each node
fori=0 to n-1 do
    if(i!=SN)
        begin
            printf("\nDistance of node%d=%d",i,distance[i]);
            printf("\nPath=%d",i);

            j=i;
            do
                j=pred[j];
                printf("<-%d",j);
            while(j!=FN);
        end
    end
end

```

**V. RESULTS AND DISCUSSIONS**

The experiment is implemented in MATLAB Version R2014a with an Intel Dual Core Processor running at 1.86 GHz, 4GB of RAM. Among the three key variables, called Memory Consumption, Energy and Cost of path, the first step of the simulation performs on fuzzification by converting them into input membership functions. This is performed using the tool called as membership function editor provided in the MATLAB. Each criterion in the experiment is quantified into small, medium, and large for memory consumption; low, medium, and high for Energy, minimum, moderate and maximum for the Cost of path. The input variables are segregated because the comparison of the variability becomes effective and it helps in providing better results. The If-Then rules of the experiment are formulated using a rule editor depict in Figure 5.

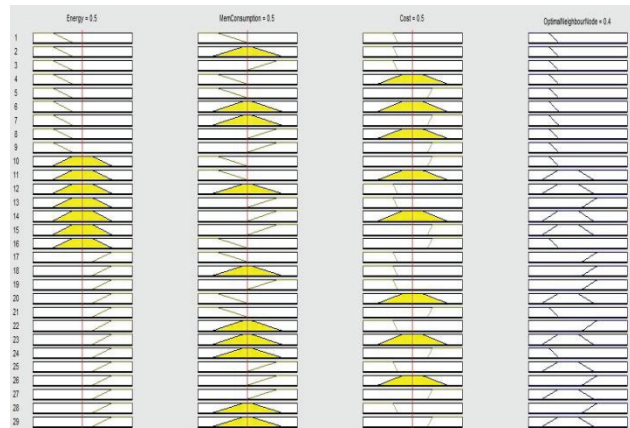


Figure 5. IF then rules –rule editor

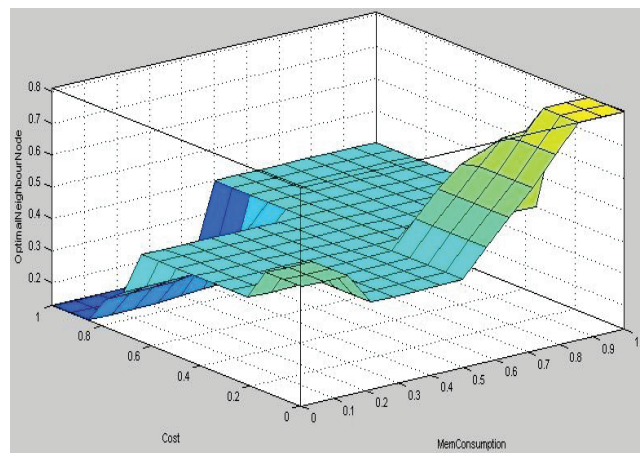


Figure 6. Output view of Memory and Cost Versus Prediction for Optimal Work station node.

The proposed work performed operation in FIS editor which handles the high-level issues. The membership function editor which defines the shapes of three membership function is associated with each criteria and rule editor for editing the list of rules. The surface viewer plots an output surface map of the system. The input vectors of the fuzzy inference engine as calculated by the simple attribute function are 0.414, 0.272, and 0.435, and the unique output generated by the Mamdani method is 0.931. All the rules have been depicted as 3D graphs called surface viewer in Figures 6, 7, and 8.

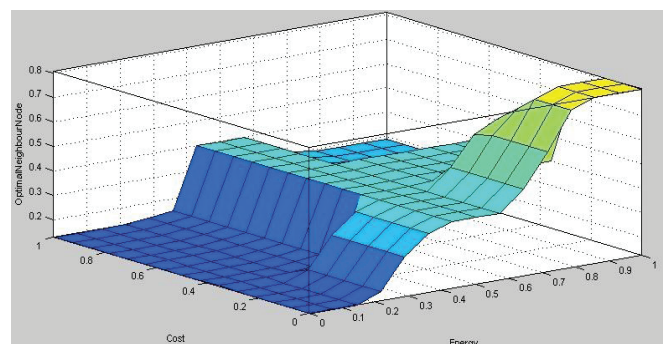


Figure 7 . Output view of Energy and Cost Versus Prediction for Optimal Work station neighbour node.

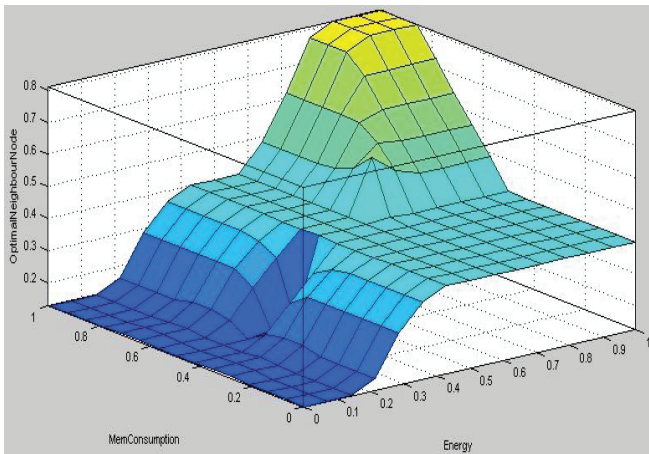


Figure 8. Output view of Energy and Memory Consumption Versus Prediction for Optimal Work station node.

## VI. CONCLUSIONS

The proposed model has applied the FAHP method, based on the node factors for successful prediction of work station for cloud service. This model considered the prediction of workstation nodes based on the factors: Energy, Memory and Cost. Fuzzy trapezoidal method is implemented to find membership function and developed rule based fuzzy inference system. The advantage of proposed system serves the best cloud service with maximum resource capability.

## REFERENCES

- [1] Butkiene R, G. Vilutis, I. Lagzdinyte-Budnike, D. Sandonavicius, K. Paulikas, "The QoGS Method Application for Selection of Computing Resources in Intercloud", ELEKTRONIKA IR ELEKTROTECHNIKA, vol.19, no. 7, 2013, pp 98-103.
- [2] Celik, M., Er, D., Ozok, F., "Application of fuzzy extended AHP methodology on shipping registry selection: The case of Turkish maritime industry", Experts Systems with Applications, 2009, vol 36, (1), pp 190-198.
- [3] Cheng, Y.K., (2000), "Development of a Fuzzy Multi-Criteria Decision Support System for Municipal Solid Waste Management", Regina, Saskatchewan.
- [4] Enea, M., Piazza, T., 2004. *Project selection by constrained fuzzy AHP*, Fuzzy Optimization and Decision Making; 3: 39-62.
- [5] Gumus, A. T., 2009, "Evaluation of hazardous wastetransportation firms by using a two step fuzzy-AHP and TOPSIS methodology" Expert Systems with Applications, vol. 36 pp. 4067-4074.
- [6] Hota H.S., Sirigiri Pavani, P.V.S.S. Gangadhar, "Evaluating Teachers Ranking Using Fuzzy AHP Technique", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, 2013, Volume-2, Issue-6, 485-488.
- [7] Jaiganesh, M & Vincent Anonykumar, 2013, "B3: Fuzzy-based data center load optimization in cloud computing", Mathematical Problems in Engineering 2013, 1-11.
- [8] Jaiganesh, M & Vincent Anonykumar, A 2014, "Fuzzy ART based User behaviour trust in Cloud computing", Seventh International Conference on artificial Intelligence and Evolutionary Algorithms in Engineering Systems, Advances in Soft computing, Volume 324, 2015, pp 341-348.
- [9] Kahraman, C, Ruan, D, Dogan, I., "Fuzzy group decision making for facility location selection," Information Sciences, vol. 157, no. 14, pp. 135153, 2003.
- [10] Saaty, T.L., 2005. "The Analytic Hierarchy and Analytic Network Process for the mesurement of intangible criteria and for decision making In Multiple Criteria Decision Analysis: State of the Art Surveys." International series in operations research management science, Vol.78, Springer
- [11] Tolga, E., Demircan, M. L., and Kahraman, C., (2005), *Operating System Selection Using Fuzzy Replacement Analysis and Analytic Hierarchy Process*, International Journal of Production Economics. 97, 89-117.
- [12] P.J.M. van Laarhoven, W.Pedrycz, "A fuzzy extension of Saaty's priority theory", Journal Fuzzy Sets and Systems. vol. 11, no. 1-3, pp.199-227, 1983.
- [13] Pham Phuoc Hung, Tuan-Anh Bui, Kwon Soonil, Eui-Nam Huh, "A New Technique for Optimizing Resource Allocation andData Distribution in Mobile Cloud Computing", ELEKTRONIKA IR ELEKTROTECHNIKA, vol.22, no.1, pp. 73-80, 2016.
- [14] Vendhan D, R.K.Selvakumar, "Color Contrast Enhancement Based On Fuzzy Model For Thinprep Cervical CellImages "Proceedings of the IEEE International Conference on Computational Intelligence and Computing Research, 2010.