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Fuzzy Logic Based Location Estimation

Pragnya Parimita Mahapatra
M.Tech Scholar Of Eastern Academy Of Science & Technology. BPUT., Odisa
M.Sc (IT), Ravenshaw University, Odisha , India

Abstract:
In this paper, proposed fuzzy based localization method is described in detail. Two different Fuzzy systems, i.e. Sugeno and Mamdani, are considered for locating the sensor node, based on the connectivity and RSSI. The results of RSSI are directly taken from the paper "A New Fuzzy based Localization Error Minimization Approach With Optimized Beacon Range", [14]. I first consider Mamdani FIS because it is relatively simple, easy to implement & fits according to the human thought process. Then I use TSK for the same.

1.Introduction

Wireless sensor network consists of a set of sensor nodes deployed randomly in the large area to monitor the parameters of interest. These nodes are categorized as: anchor nodes and normal sensor nodes. Anchor nodes are special type of nodes embedded with GPS or other facility to obtain their position within the network. If feasible, these nodes can also be placed manually at known positions within the network. It is assumed that n numbers of anchor nodes are deployed in the sensing field. The position of anchor nodes is assumed as (X_1, Y_1), (X_2, Y_2)… (X_n, Y_n). Anchor nodes transmit periodic beacon signals containing information regarding their respective positions with overlapped region of coverage. Sensor nodes are deployed in the sensing field, with randomly distributed positions. These sensor nodes localize themselves with the help of beacon signals, transmitted by the anchor nodes. Each sensor node collects the received signal strength information (RSSI) of all connected adjacent anchor nodes through beacon signal and RSSI is used to obtain the edge weights of the anchor nodes for weighted centroid localization. Time division multiplexing (TDM) technique is used to avoid interference of beacons transmitted by neighbouring anchor nodes. The radio transmission range of all nodes is assumed to be identical and perfectly spherical.

2.Calculating The Edge Weights Using Fuzzy Inference System

The sensor node collects the received signal strength information (RSSI) values of all connected adjacent anchor nodes. The edge weights of anchor nodes need to be calculated for finding sensor node position. In this paper, fuzzy systems with triangular membership function for input (RSSI) and output (weight) have been used. The input variable is the RSSI
From anchor node and can take values in the interval [0, RSSImax], where, RSSImax is the maximum RSSI value. The output variable is the edge weight of each anchor node for a given sensor node and can take value in the interval [0, Wmax], where Wmax is the maximum weight. For modelling the fuzzy logic inference system (FLI), If-Then rules have to be considered, which follow the basic principle that if a sensor node senses the high powered signal from an anchor node, the anchor node is likely to be in close proximity to the given sensor node and hence is assigned high weight. Conversely, if a sensor node is connected to an anchor node but senses a low powered signal, the anchor node is likely to be far from the given sensor node and hence is assigned a low weight. Consequently, the fuzzy rule bases are used and tuned the membership functions.

3.Edge Weight Calculation Using The Mamdani Fuzzy Inference System

For Mamdani FLI based localization method, the fuzzy logic system has been modelled using the Mamdani fuzzy inference system [25] [26]. Where, the inputs (RSSI) have been decomposed into three triangular membership functions namely: low, medium, and high, and output (Weights) space have been decomposed into five triangular membership functions namely: very low, low, medium, high, and very high,

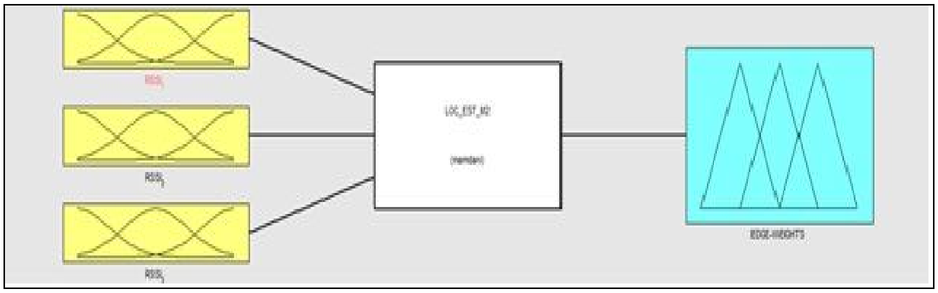


Figure 1: Mamdani Le

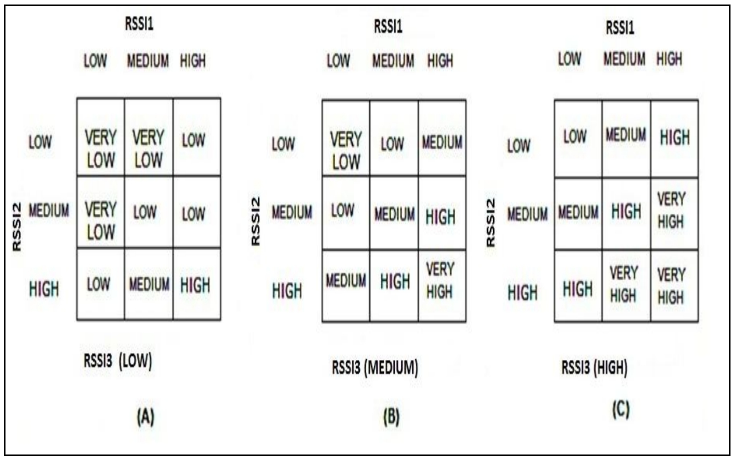


Figure 2: Fuzzy Rules For Mamdani LE

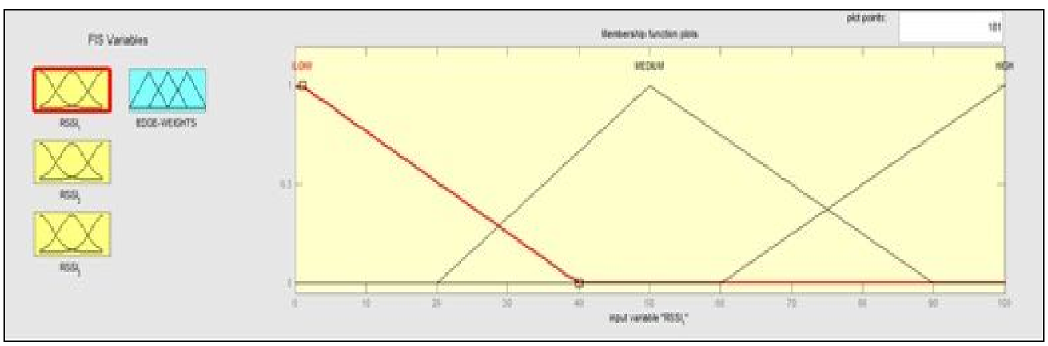


Figure 3: Input Parameter$_1$ To Mamdani_LE (RSSI$_1$)

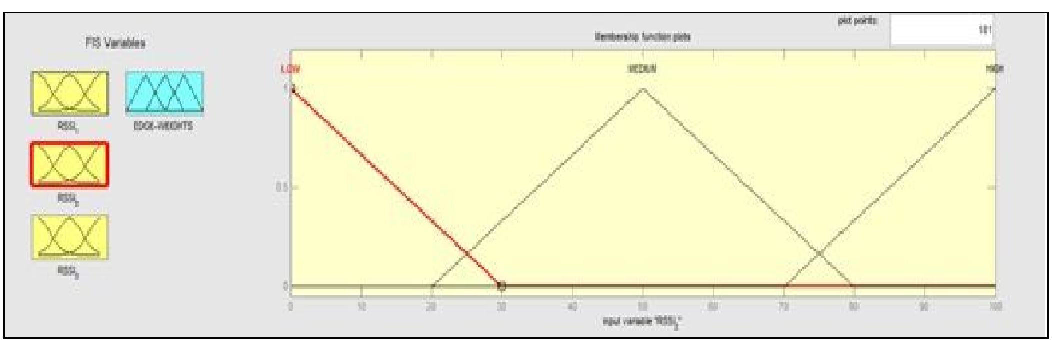


Figure 4: Input Parameter$_2$ To Mamdani_LE (RSSI$_2$)

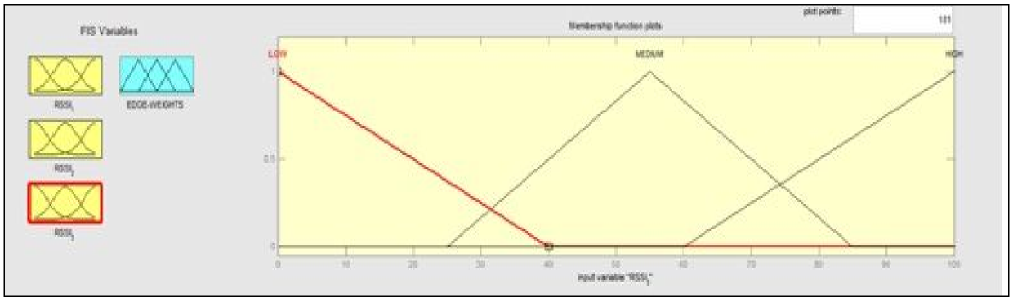


Figure 5: Input Parameter$_3$ To Mamdani_LE (RSSI$_3$)

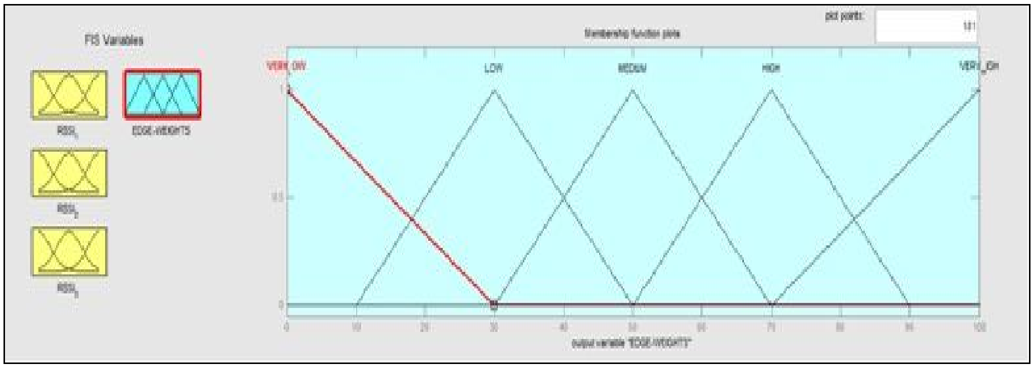


Figure 6: Output Parameter From Mamdani_LE (Edge_ Weights)

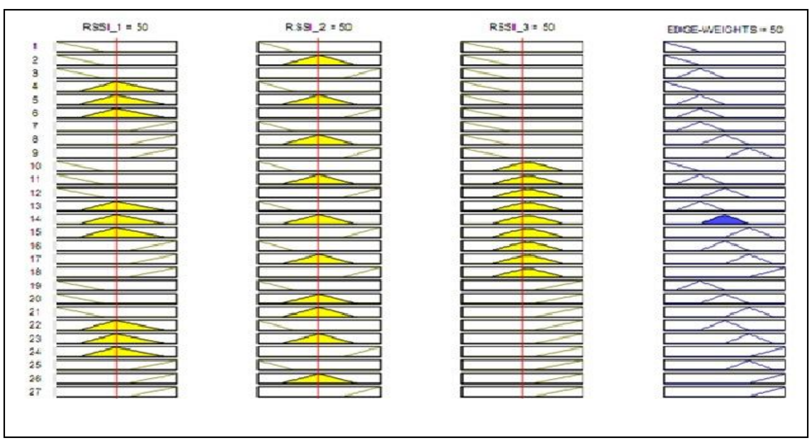
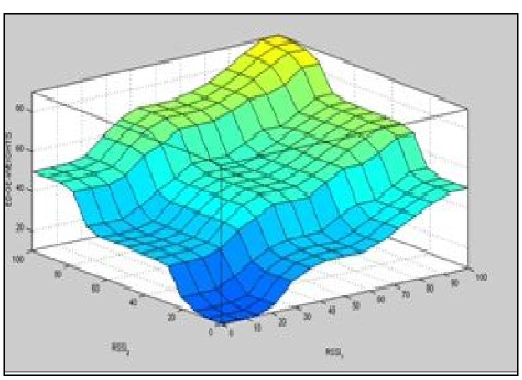


Figure 7: Simulation Of Fuzzy Rules In Mamdani_LE



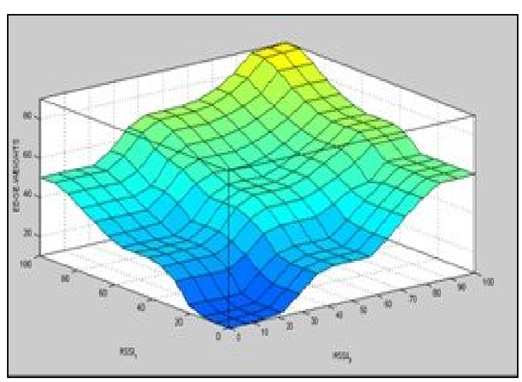


Figure 8: Surface View Of RSSI$_1$ And RSSI$_2$ VS Edge Weights

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Figure 9: Surface View Of RSSI$_1$ And RSSI$_3$ VS Edge Weights

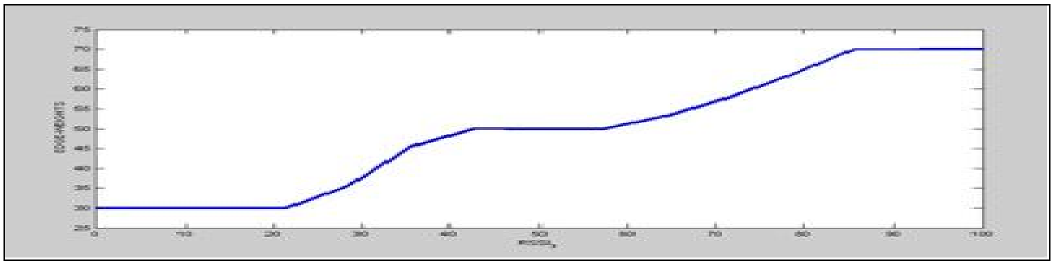

Figure 10: RSSI Versus Edge Weights In Mamdani_LE

- **Test Results using MAMDANI FIS**

INPUTS			**OUTPUT**
$RSSI_1$	**$RSSI_2$**	**$RSSI_3$**	**Edge-Weights**
3	4	5	9.86
15	45	15	10.8
27	80	20	30
50	25	30	33.9
50	50	30	37.8
50	80	20	30
80	10	15	25.7
85	50	15	46.4
85	85	15	60.5
35	35	55	45.8
15	55	55	30
15	95	55	50
45	15	55	30
45	45	45	50
45	95	55	70
85	15	55	45.9
85	55	55	66.4
85	95	55	84.7
15	15	95	30
15	55	95	60
15	55	95	60
45	15	95	50
45	45	95	70
45	95	95	90.1
85	15	95	65.9
85	45	95	84.7
85	85	95	88.6

Table 1: Edge Weights Using Mamdani FIS

From Mamdani FIS I found that:
A (i, j) = no of input linguistic variables i.e. (j=3) (L, M, H)
B_i = no of outputs linguistic variables i.e. (i=5) [VL, L, M, H, VH]
I=no of implications i.e. 27
n=3
From the Table 1.1, I can analyze that in MAMDANI, the minimum edge weight is 9.86 whereas the maximum edge weight is 90.1 as per the simulations.27 implications are shown in the table.

4.Edge Weight Calculation Using TSK Fuzzy Inference System

For TSK FLI based localization method, fuzzy system has been modelled using Sugeno method of fuzzy inference [999]; which is similar to the Mamdani method in many aspects. The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are exactly the same.

The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant. In my approach I have considered a liner output membership function and have decomposed the input (RSSI) into three triangular membership functions namely: low, medium, high. The output has been decomposed into five linear symmetrical functions namely: very low, low, medium, high, and very high. Sugeno systems do not have the output membership function plot. The defuzzification is considered to be weighted average.

- **Test Results using TSK FIS**

INPUTS			**OUTPUT**
$RSSI_1$	**$RSSI_2$**	**$RSSI_3$**	**Edge-Weights**
3	4	5	0
15	45	15	0
27	80	20	0.5
50	25	30	0.5
50	50	30	0.7
50	80	20	0.5
80	10	15	0.333
85	50	15	0.917
85	85	15	0.1
35	35	55	0.898
15	55	55	0.5
15	95	55	1
45	15	55	0.5
45	45	45	1
45	95	55	0
85	15	55	0.9
85	55	55	0.167
85	95	55	0.833
15	15	95	0.5
15	55	95	0.5
15	55	95	0.5
45	15	95	1
45	45	95	0
45	95	95	1
85	15	95	0.2
85	45	95	0.833
85	85	95	1

Table 2: Edge Weights Using TSK FIS

From TSK FIS I found that:
A (i, j) = no of input linguistic variables i.e. (j=3) (L, M, H)
B_i = no of outputs linguistic variables i.e. (i=5) [VL, L, M, H, VH]
I=no of implications i.e. 27
n=3
From the table 1.2 I can analyze that in TSK; the minimum edge weight is 0 where as the maximum edge weight 1 .As per the simulations.27 implications are shown in the table.

5.Weighted Localization Algorithm

After calculating edge weights using Sugeno or Mamdani fuzzy inference system, I used the weighted centroid algorithm to estimate the sensor node position, using the position of adjacent connected anchor nodes (X_1, Y_1), (X_2, Y_2)… (X_n, Y_n) respectively. Non anchor sensor node calculates its position as per following weighted centroid formula [14][15]: which was first proposed by Kim and Kwon [19]. In this improved version, location of sensor node is calculated by using edge weights of anchor nodes connected to sensor node, and each sensor node computes its position by

$$(X_{est}, Y_{est}) = \left(\frac{w1.X_1 + \cdots + wN.X_n}{\sum_{i=1}^{N} w_i}, \frac{w1.Y_1 + \cdots + wN.Y_n}{\sum_{i=1}^{N} w_i} \right) \quad \textbf{(1.1)}$$

Where w_i is the edge weight of i^{th} anchor node connected to the sensor node and n is the number of adjacent connected anchor nodes.

6.Comparison & Results

After simulation is done using MATLAB® 7.9 and Fuzzy Logic Tool Box I compare the RSSI,Centroid,Mamdani and TSK techniques in terms of its root mean square error. The final outcome of this simulation is enlisted in the following table i.e.

LOCATION ESTIMATION TECHNIQUES	MAX RMS ERROR (in meter)	MIN RMS ERROR (in meter)	AVG RMS ERROR (in meter)
RSSI_LE	24.42646	1.365295	6.528623
CENTROID_LE	4.5649	0	1.521
MAMDANI_LE	4.5382	0	1.512
TSK_LE	4.4874	0	1.495

Table 3: Location Error Analysis

Here from the above table I can analyze that the maximum rms error, minimum rms error as well as average rms error w.r.t. 4 location estimation techniques i.e. RSSI_LE, CENTROID_LE, MAMDANI_LE & TSK_LE.

From the simulation I found that the maximum error in case of RSSI_LE is found to be 24.42646 meter, in case of CENTROID_LE is 4.5649 meter, in case of MAMDANI_LE is 4.5382 meter and in case of TSK_LE is 4.4874 meter.

The minimum error in case of RSSI_LE is found to be 1.365295 meter, where as in case of CENTROID_LE, MAMDANI_LE and TSK_LE is found to be 0 meter.

The average error in case of RSSI_LE is found to be 6.528623 meter, in case of CENTROID_LE is 1.521 meter, in case of MAMDANI_LE is 1.512 meter and in case of TSK_LE is 1.495 meter.

7.Conclusion & Future Work

From this work I can conclude that RSSI is the most error prone if used alone for location estimation followed by the standard Centroid method. When a fuzzy inference system is used for the location estimation it gives better accuracy than the traditional RSSI technique.

The TSK based location estimation technique gives better accuracy than the Mamdani based technique but for realistic world Mamdani is well suited for human inputs.

This work can further be extended by a proposing Hybrid Fuzzy Localization System. Probabilistic fuzzy rule base approach can also be used as an extension for this thesis work. This work can also be extended for cellular positioning using fuzzy rule based techniques.

8.References

1) Paul J. Kuhn ,"Location Based Services in Mobile Communication Infrastructures", ,Electronic Communication (AEU) 58,2004.
2) A. Roxin, J. Gaber, M. Wack, A. Nait-Sidi-Moh," Survey of Wireless Geolocation Techniques"IEEE Globecom Workshop,page 1-9,2010.
3) Mussa Bshara, Umut Orguner, Fredrik Gustafsson, and Leo Van Biesen," Fingerprinting Localization in Wireless Networks Based on Received-Signal-Strength Measurements: A Case Study on WiMAX Networks., IEEE Transactions on Vehicular Technology, vol. 59, no. 1, January 2010.
4) Shu Wang, Jungwon Min, Byung K.Li,"Location Based Services for Mobiles: Technologies & Standards", LG Electronics Mobile Research, USA2008.
5) C.Frederic,"Location Service Study Report, D2.3.1", Mobile and Vehicles Enhanced Services IST-2000-30041, 2002.
6) Zhetao Li, Renfa li et al, "Survey of Localization Techniques in Wireless Sensor Network", Information Technology Journal 9(8), PP 1754-1757, 2010
7) J. Jasper Gnana Chandran , S. P. Victor ,"An Energy Efficient Localization Technique Using Particle Swarm Optimization in Mobile Wireless Sensor Networks", American Journal of Scientific Research, ISSN 1450-223X Issue 8, PP 33-48,2010
8) Caffery, J. J., "Wireless location in CDMA Cellular Radio Systems",Kluwer Academic, Boston, 2000.
9) Raghavendra V. Kulkarni, & Ganesh Kumar Venayagamoorthy, "Bio-inspired Algorithms for Autonomous Deployment and Localization of Sensor Nodes", IEEE Transactions on Systems, Man, And Cybernetics Part C: Applications And Reviews, Issue 5, Volume 40, 2010
10) Li, W., and Liu, P., "3D AOA/TDOA emitter location by integrated passive radar/GPS/INS systems", Proceedings of 2005 IEEE International Workshop on VLSI Design and Video Technology, PP 121 – 124, 28-30 May 2005.

11) Yao Q, Tan S.K., Ge. Y, Yeo B.S., and Yin, Q., “An area localization scheme for large wireless sensor networks”, IEEE 61st Vehicular Technology Conference, VTC 2005, Volume 5, PP. 2835 – 2839, 30 May-1 June 2005
12) Isaac Amundson and Xenofon D. Koutsoukos, “A Survey on Localization for Mobile Wireless Sensor Networks”, MELT 2009, LNCS 5801, PP. 235–254, 2009
13) Mahnaz Kadkhoda, Mohammad R.& Akbarzadeh Totounchi,“A Probalistic Fuzzy Approach for Sensor Location Estimation in WSN”.
14) Vinay Kumar ,Ashok Kumar & Surender Soni “A New Fuzzy based Localization Error Minimization Approach With Optimized Beacon Range",2nd International Conference and workshop on Emerging Trends in Technology (ICWET) 2011 Proceedings published by International Journal of Computer Applications® (IJCA) .
15) Sukhyn Yun,Jaehun Lee,Wooyoung Chung & Euntai Kim “Centroid Localization Method In Wireless Sensor Networks using TSK Fuzzy Modelling",.
16) Niculescu, D., and Nath, B., “Ad Hoc Positioning System (APS) Using AoA”, 2003.
17) Qi, Y., Kobayashi, H., and Suda, H., “Analysis of Wireless Geolocation in a Non-Line-of-Sight Environment”, IEEE Transactions on wireless communications, vol. 5, no. 3, March 2006.
18) Andrija S. Velimirovi’, Goran Lj. Djordjevi´, Maja M. Velimirovi´ and Milica D. Jovanovi´ “A Fuzzy Set-Based Approach to Range-Free Localizationin Wireless Sensor Networks", SER.: ELEC. ENERG. Volume. 23, No. 2, PP 227-244, August 2010,
19) Kim, S. Y., & Kwon, O. H, “Location estimation based on edge weights in wireless sensor networks”. Journal of Korea Information and Communication Society 30, 10A, 2005.
20) Azat Rozyyev, Halabi Hasbullah & Fazli Subhan, "Indoor Child Tracking in Wireless Sensor Network Using Fuzzy Logic Technique", Research Journal of Information Technology 3(2): PP 81-92, 2011, ISSN 1815-7432/DOI:10.3923/rjit.2011.81.92.
21) Balaram Singh, Santosh Kumar Sahoo,” A Comparative View on Anchor Based, Range Based Localization Systems using AOA, TOA & RSSI”, Proceedings of 4th National Conference on Communication Technologies,NCCT’12,PP 205-210,March 02,2012.
22) Chong Liu, Tereus Scott, Kui Wu, Dan Hoffman," Range-Free Sensor Localization with Ring Overlapping Based on Comparison of Received Signal Strength Indicator".2007
23) T. S. Rappaport, Wireless Communications: Principles and Practice, 2nd ed. Prentice Hall PTR, 2009
24) Fuzzy logic Tool Box, by MATLAB
25) Fuzzy Tutorial by MATLAB
26) M.Hellman,”Fuzzy Logic Introduction”