Modelling of Artificial Intelligence based Localization Algorithm for Wireless Sensor Networks

Pramod Kumar K
Dept. of Electronics and Communication Engg.
REVA Institute of Technology and Management,
Bangalore, India.

Manjunath R Kounte
Dept. of Electronics and Communication Engg.
REVA Institute of Technology and Management,
Bangalore, India.

ABSTRACT
Wireless sensor networks (WSN) are deployed where human reach is difficult of even impossible WSN are responsible for measuring data in the environment in which they are deployed. So it is meaningless if the location data is unavailable. Many localization algorithms are proposed to increase accuracy and sensor lifetime, decrease processing time and cost requirements. In this paper a survey and has been done on node localization algorithm which involves usage of both neural network and non-neural network approaches and modelling node localization in 2D using a Fuzzy-based Localization Algorithm.

General Terms
Node localization, Artificial Intelligence, Sugeno-type FIS.

Keywords
Wireless Sensor Networks (WSNs) Artificial Intelligence

1. INTRODUCTION
Wireless Sensor Networks (WSNs) are collection of autonomous inexpensive sensors that are distributed spatially. WSNs are equipped with variety of sensors for sensing pressure, infrared, radar, sonar, orientation and few even are equipped with cameras. Sensor nodes are fitted with at least one microcontroller that provides processing capability, one RF transceiver antenna to allow communication and for power they rely on solar cells or small batteries with limited power. The role of sensors is to convert the physical conditions sensed into electrical signals. These signals are transferred to few special sensors that are centrally collated and are then analyzed. There are wide range of WSN applications like smart homes, disaster relief, and search and rescue operations. It also has applications in surveillance of armed troops and tracking and detection of targets [1].

One of the fundamental challenge in the field of wireless sensor networks is node localization. Node localization refers to determining the physical coordinates of the deployed nodes in the network. Sensor nodes are supposed to be monitoring some processes or system variables and report its origin to take necessary actions. Therefore monitoring these without knowing the exact position of sensor nodes is a meaningless action. One way of accomplishing this is by using GPS. Since the sensors are packed with limited source, use of GPS shortens its life and also increases production cost. Use of GPS also requires unobstructed line of sight with sky which makes it difficult to deploy the sensors indoors and in urban canopy. Another way of node localization is to use few anchor (beacon) nodes in the network which has preprogrammed GPS location using which it is possible to localize non anchor nodes.

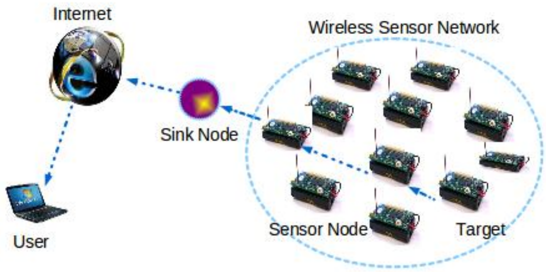

Fig 1: Wireless Sensor Network Architecture

Localization algorithms proposed to overcome drawbacks of GPS in node localization can be classified as range based and range free categories [2].

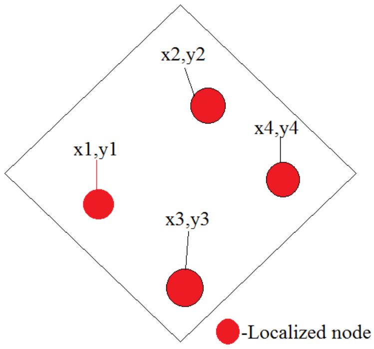

Fig 2: Node localization

In range based algorithm it is required to have precise internodes measurements like angle and distance which requires additional hardware for these measurements. Moreover it makes this implementation consume more energy and is also expensive to design. In range free algorithm the angle and distance are assumed to be unavailable. Hence it relies only on proximity of anchor nodes. Although range based algorithm yields accurate results, range free algorithm provides faster results and is more economical [3].

Fuzzy logic is an approach to computing based on degrees of truth rather than Boolean logic as true or false. Unlike the Boolean logic, fuzzy logic has values between 0 and 1 and it is used as extreme case of truth. Fuzzy logic seems closer to the way human brains work. We aggregate data form partial truths which further aggregate into higher truths, after exceeding certain threshold causes motor reaction. It incorporates a simple rule-based “if x and y then z” approach to a solving control problem rather than attempting to model a system mathematically.

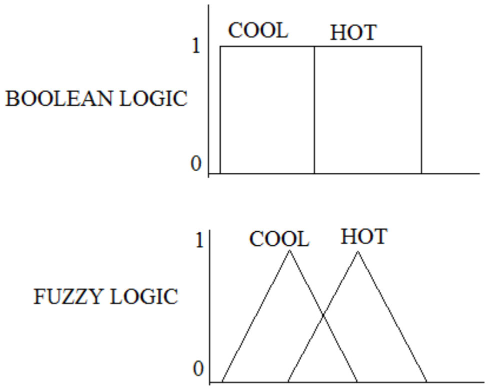

Fig 3: Simple Fuzzy Logic

Artificial intelligence is a branch of science that deal with helping machines to find solutions to complex problems in a more human like way. This generally involves borrowing characteristics of human intelligence and applying it as algorithm.

2. RELATED WORK

A lot of research has been done for sensor node localization which includes 2D, 3D localization for static and mobile nodes using various algorithms based on use of GPS systems, fuzzy systems, artificial neural networks and non-neural network approaches.

Centroid algorithm [4] is used for node localization using GPS system. In this algorithm the beacon nodes are placed in grid configuration. The node's location is estimated as centroid of the location of all beacon nodes heard. Localization accuracy heavily relies on the percentage of deployed beacon nodes, separation distance between two adjacent reference points and transmission range of these reference points. This approach was nevertheless useful for an application which requires precise node locations.

Monte Carlo Localization [5] with probabilistic technique is used where a single beacon node passes throughout the deployed area. Location of node is computed on the beacon instead on the sensors. Possible sensor locations are represented by particle samples for each node, which are updated as the beacon passes through the network. This arrangement relieves heavy processing needed for accurate localization. Better accuracy can be achieved by increasing network connectivity.

Simultaneous Perturbation Stochastic Approximation (SPSA) [6] is a simple centralized algorithm that estimates the location of the non-anchor nodes based on minimizing the summation of the estimated error of all neighbours. This improved error reduction was obtained by modifying constrained optimization technique. Although this algorithm achieves higher performance, the location information from the neighbouring nodes may contain errors if the particular neighbour is a non-anchor node, which adversely impacts the estimation.

LSVM [7] is a range free localization algorithm based on SVM learning. The algorithm assumes that a sensor node may not communicate directly with a beacon node and only connectivity information i.e., hop distance only, is used for location estimation. A modified mass spring optimization (MMSO) algorithm was also proposed to further improve the estimation accuracy of LSVM

2D and 3D Weighted Centroid Localization (2D and 3D WCL) [8] is used for localizing nodes in 2D and 3D. This algorithm has shown improved location accuracy than the Monte Carlo Localization algorithm. It restricts the number of anchor nodes involved in the localization process. It also reduces error caused by variations in RSSI values. WCL is simple, cost efficient and robust for large scale and fixed WSNs which makes it suitable for practical applications.

COmplexity Reduced Trilateration Localization Approach (COLA) [9] was initially proposed for 2D localization and was extended for 3D. Here a set of Super Anchor (SA) nodes are utilized for range estimation. Sensor nodes need to find reference node that lie on same x-y plane. The COLA approach achieves accuracy but to achieve good results, SA has to be distributed uniformly which is hard to achieve in reality.

Time Difference of Arrival (TDOA) information with neural network (NN) [10] for node localization was proposed. This approach used two artificial neural network models- Back Propagation Network (BPN) and Radial Basis Function (RBF) Network for WSN's node localization problem. TDOA is used to calculate distance information from anchor node to sensor node. This information is used to train NN models. It shows that there is considerable improvement in RMSE for node localization.

FuzzyART (Fuzzy Adaptive Resonance Theory) [11] neural network was proposed for categorization of the position of the robot based on acquired and pre-processed sensor data (percept), the graph is used to estimate position by matching the current sensory reading category with an existing node category. The ultrasound sensor used is prone to miss reading the distance if the object is a surface that has large angle with ultrasound waves. These led to imprecise location estimation.

Fletcher-Reeves update-based conjugate gradient (CG) multi-layered feed forward neural network [12] is a connectivity based localization of a large number of sensor nodes in 2D network on basis of information gathered from beacon nodes. This algorithm employs a classification scheme where the location of sensor is simultaneously estimated in both x and y axis.

A distributed localization is addressed using Particle Swarm Optimization (PSO) and Comprehensive Learning Particle Swarm Optimization (CLPSO) [13] which are bio inspired algorithms. The performances of both algorithms were studied based on parameters like nodes localized, computational time and localization error. These approaches aim to be more energy efficient since the use of distributed localization which reduces the number of transmissions to base station. It was observed that computational time required for PSO is less than CLPSO, however CLPSO gives more accurate results since its localization errors are much less compared to PSO.

3. PROPOSED WORK

Proposed work involves modelling of node localization algorithms

3.1 A Fuzzy-Based Localization Algorithm for Wireless Sensor Networks

Proposed algorithm is a range free algorithm. The sensor nodes periodically listens to beacon signals from at least four anchor nodes and calculates its position from anchor nodes using RSSI (received signal strength indicator) values using Sugeno-type fuzzy interface system(FIS) and later sends this location information to anchor nodes.

The relationship between the distance and the weight can be described as follows:
IF R is A, THEN W is W=f(A), where R is the RSSI, W is the weight, A is a set of RSSI truth values, and f(A) is a polynomial function in the input of A which describes the output of the system within the fuzzy region specified in the rule. Weight values that represents certain distance is obtained based on fuzzy rules.

The output weight value W has nine truth values:
W= {very very low, very low, low, medium low, medium, high, very high, very very high}, where each one has following fuzzy region:
W(0)= Very very low=[-85 -70], W(1)= Very low=[-80 -62.5], W(2)=Low=[-70 -52.5], W(3)=Medium low=-[62.5 -42.5], W(4)=Medium=[-52.5 -32.5], W(5)=High=[-32.5 -15], W(6)=Very high=[-22.5 -10], W(7)=Very very high=[-15 0]

Table 1. Shows Sugeno-type fuzzy interface system is used to calculate distances from beacons.

The output weight values from FIS and the position of the anchor nodes are then used as input arguments in the weighted average formula to calculate estimated position (X_{est}, Y_{est}) of a sensor node as follows:

Table 1. Sugeno-type FIS

Rule	If: RSSI is	Then: Weight is
1	Very very low	Very very high
2	Very low	Very high
3	Low	High
4	Medium low	Medium high
5	Medium	Medium
6	Medium high	Medium low
7	High	Low
8	Very high	Very low
9	Very very high	Very very low

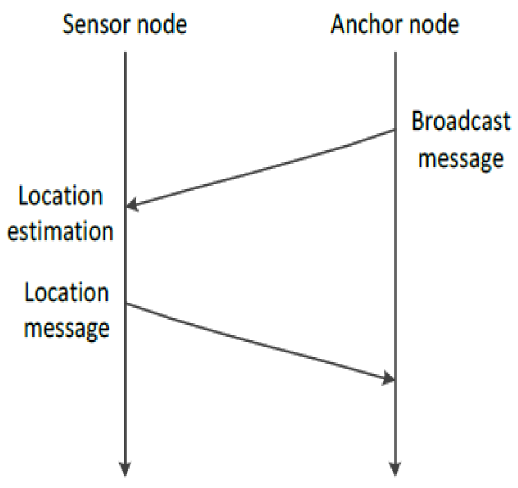

Fig 5: Communication process

$$Xest = \frac{\sum_{i=n}^{n}(xi * wi)}{\sum_{i=1}^{n} wi}$$

$$Yest = \frac{\sum_{i=n}^{n}(yi * wi)}{\sum_{i=1}^{n} wi}$$

where, Xi and Yi are the x-y coordinates of the i^{th} anchor node, and w_i is the weight value of the i^{th} anchor node. [3]

4. SIMULATION TOOL

MATLAB will be used to simulate the proposed algorithm and performance of the algorithm will be evaluated. MATLAB Fuzzy logic tool box will be used to implement the fuzzy logic in decision making.

5. CONCLUSION

A survey has been done on various Wireless Sensor node localization algorithms that involve both neural network based and non-neural network based approaches. It has been found that using Artificial Intelligence in node localization has promising results with good accuracy, less computation time, and more energy efficiency. A proposal has been made for modelling node localization algorithm involving 2D localization using fuzzy logic. Using nine truth values gives better weight values and localizes the node more accurately.

6. REFERENCES

[1] J. Wang, Z. Cheng, L. Jing, and T. Yoshida, “Design of a 3D localization method for searching survivors after an earthquake based on WSN,” The 3rd International Conference on Awareness Science and Technology (iCAST), vol. 27, no. 30,pp.221-226, 2011

[2] A. Pal, “Localization algorithms in wireless sensor networks: current approaches and future challenges,” Network Protocols and Algorithms, vol. 2, no. 1, pp. 45-74, 2010

[3] M. Abdelhadi, M. Anan, and M. Ayyash, “Efficient Artificial Intelligent-based Localization Algorithm for Wireless Sensor Networks”, Cyber Journals: Multidisciplinary Journals in Science and Technology, Volume 3, pp. 10-18, 5 May Edition, 2013

[4] N. Bulusu, J. Heidemann, and D. Estrin, “GPS-less low cost outdoor localization for very small devices,” IEEE Personal Communication Magazine, vol. 7, no. 5, pp. 28-34, 2000

[5] Rui Huang and Gergely V. Za´ruba, “Monte Carlo localization of wireless sensor networks with a single mobile beacon”, Springer Science and Business Media, LLC 2008.

[6] Mohammad Abdul Azim, Zeyar Aung, Weidong Xiao, Vinod Khadkikar and Abbas Jamalipour, “Localization in Wireless Sensor Networks by Simultaneous Perturbation Stochastic Approximation Technique”

[7] Duc A. Tran, Member and Thinh Nguyen, “Localization in Wireless Sensor Networks based on Support Vector Machines”, National Science Foundation under Grant No. CNS-0615055

[8] Lisheng XU, Ke Wang, Yuqi Jiang, Fei Yang, Yuhang Du and Qingchao Li, “A Study on 2D and 3D Weighted Centroid Localization Algorithm in Wireless Sensor Networks”, 3rd International Conference on Advanced Computer Control (ICACC 2011), pp. 155-159, 2011

[9] S.Chia-Yen and P.J.Marron, “COLA: Complexity-Reduced Trilateration Approach for 3D Localization in Wireless Sensor Networks”, The 4th International Conference on Sensor Technologies and Applications (SENSORCOMM), pp. 24-32, 2010

[10] Prince Singh and Sunil Agrawal, “TDOA Based Node Localization in WSN using Neural Networks”, IEEE International Conference on Communication Systems and Network Technologies’, pp. 400-404, 2013

[11] Petre Lameski, Andrea Kulakov, Danco Davcev, Learning and position estimation of a mobile robot in an indoor environment using FuzzyART neural network”, IEEE/ASME International Conference on Advanced Intelligent Mechatronics", pp. 770-774, 14-17 July,2009

[12] Amitava Chatterjee, “A Fletcher–Reeves Conjugate Gradient Neural-Network-Based Localization Algorithm for Wireless Sensor Networks”, IEEE Transactions on Vehicular Technology”’vol.59, No.2, Febraurary 2010

[13] Maneesha V. Ramesh, Divya P. L., Rekha P. and Raghavendra V. Kulkarni, “Performance Enhancement in Distributed Sensor Localization using Swarm Intelligence”, IEEE International Conference on Advances in Mobile Network, Communication and Its Applications, pp.103-106, 2012