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Localization Using Classical MDS & NN Implementation

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Abstract

The process of accurate position estimation of sensor nodes, called Localization is vital for many position-dependent applications in wireless sensor networks. Distance estimation between sensor nodes is the fundamental step before any algorithm is applied to obtain accurate estimate of nodes. Most ranging methods give noisy estimate of distance vector between nodes. This work attempts to reduce the effect of noisy estimated range by utilizing neural network. The results suggest that neural networks could be promising domain to achieve higher localization accuracy.

1. Introduction

In recent years, benefiting from advances in wireless communication and Micro electro mechanical systems technology (MEMS), it became naturalistic for producing a flyspeck sensor node which integrate small size of sensor, processor, memory, power supply in it [1]. Wireless Sensor networks (WSNs) uncover great potential to give economical as well as practical solution to myriad military and civilian applications [2, 3] including environmental monitoring, habitat monitoring, precision agriculture, animal tracking, disaster rescue, etc. In almost all of these applications sensor nodes must collect its data with location of event. Collected data with location helps scientists to perform analysis on incoming information from corresponding sensors [4, 5]. The process of knowing the location of event occurrence called "Localization" [6], is a crucial issue in WSNs.

This paper focuses on localization techniques of sensors in a network. A very prominent localization algorithm called MDS is implemented and the results are evaluated to obtain the degree of inaccuracy - called *stress*. Further work is carried out to reduce the *stress* by implementing neural network (NN) approach. The results obtained after (NN) implementation is encouraging, however the feasibility of such implementations have to be analyzed.

This paper is organized as follows. Section 2 presents the background of wireless sensor network and sensor node localization. Related work is discussed in Section 3. Section 4 presents MDS algorithm and analysis of this particular algorithm followed by description of neural network and localization then it contains the simulation and evaluation results. Section 5 contains conclusion and future direction.

2. Localization in Wireless Sensor Networks.

A WSN comprises of few to thousands of nodes that are spatially distributed and connected wirelessly that are used to monitor physical or environmental condition such as temperature, sound, pressure etc. and to cooperatively pass their data through the network to a main location. A sensor node [7] might vary in size, the cost of sensor nodes is similarly variable depending on the complexity and function of individual sensor nodes. Unlike current information service such as those on the internet where information can easily get stale or useless because it is too generic, sensor network promises to couple end users directly to sensor measurements and provide information i.e. precisely localized in time and or space, according to user's demand [8].

Localization, i.e., location estimation of source of occurrence of events is essential in most wireless sensor network applications. For estimating the location, human configuration is a simple way but impossible for large networks and some human restricted area like in jungles, volcanoes [9] and also where sensors are mobile. Another way is to directly add GPS on the sensors but use of GPS is not feasible as (i) it is not suitable for indoors and underwater sensor network, (ii) it require LOS condition, (iii) size of sensors shall increase on adding GPS to it and finally (iv) power consumption of GPS is more which becomes a deterrent to its use in WSN [10 11].

Basically localization technique are classified into two groups - range based and range free techniques. The taxonomy of such techniques is given in figure 1 [11-20].

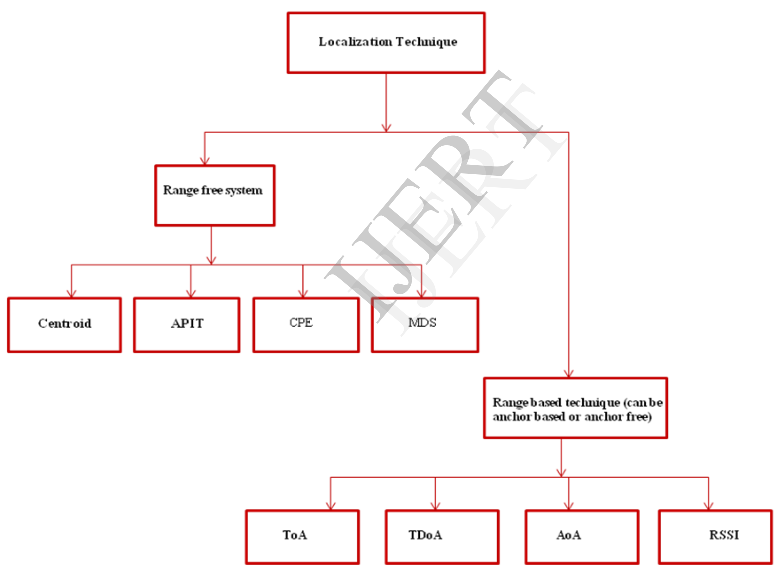

Figure 1. Classification of localization techniques

*APIT- Approximation Point In Triangle
* CPE - Convex Position Estimation
* MDS - Multidimensional Scaling
* ToA- Time of Arrival
* TDoA- Time Difference of Arrival
* AoA- Angle of Arrival
*RSSI- Received Signal Strength Indicator.

3. Related Work

Yi Shang *et al*. in [21] proposed MDS-MAP algorithm that uses connectivity information - who is within communication range of whom - to derive location of nodes in a network. Result demonstrate that given algorithm is more robust to measurement error than previous algorithm. Yi Shang *et al*. in [22] showed a new variant method MDS-MAP(P) standing for MDS-MAP using patches of relative maps, execute in distributed fashion. Result yielded not only preserve the good performance of original MDS on relatively uniform layout but also perform much better than the original on a irregularly-shaped network. Georgious Latsoudas *et al*. in [19] propose a two-stage MDS algorithm that employs an algebraic initialization procedure followed by gradient descent. The algebraic initialization step is based on the Fastmap algorithm [23], borrowed from the database literature. Fastmap is a linear-complexity mapping tool, which is, however, sensitive to measurement errors. Parham H. Namin *et al*. in [24] has shown that most of the localization algorithms have poor performance in irregularly shaped networks. They have applied MDS-MAP on irregular wireless sensor network based on Multidimensional Scaling. The result shows enhanced localization precision. Minhan Shon *et al*. [11] has shown that some method provide location information by node connectivity one of them is MDS-MAP, gives an accurate positioning but has computation of $O(n^3)$ in a network with n nodes resulting significant localization accuracy error in environments with holes. They have applied cluster-based MDS for range-free localization. Result shows the overcoming of shortcoming of MDS and give 23% improvement in localization accuracy.

4. Wireless sensors localization using Multidimensional Scaling(MDS):

Few algorithm whether range based or range free are based on MDS. In this technique proximities between any kind of objects(sensor nodes) are used as an input and the chief output is a spatial representation, consisting of geometric configuration of points [25]. This technique gives a good estimate of node position, but its computational cost is high O (n^3), where n is number of sensor node. Here we focus on classical multidimensional scaling(CMDS). It is the simplest case of MDS.

Let d_{rs} be the dissimilarity measure between two objects r and s, and D be the distance matrix. euclidean distance between two pints $X_r = (x_{r1}, x_{r2}, \ldots, x_{rm})$ and $X_s = (x_{s1}, x_{s2}, \ldots x_{sm})$ is to be calculated as

$$\hat{d}_{rs} = \sqrt{\sum_{k=1}^{m} (x_{rk} - x_{sk})^2}$$

where k is the value of dimension and m is number of dimension.

- Compute the square of distance matrix D as D^2 where D is an $N \times N$ matrix and N represents number of sensors or object.
- Apply double centering version to D^2, denoted by B as $B = -\frac{1}{2} JPJ$

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- J is a centering operator and compute $J = I - ee^T / N$ and e is vector of all ones.
- Compute Eigen decomposition of B as $B = UVU^T$ where U is an eigen vector and V is an diagonal containing eigen value.
- The classical coordinate matrix is $X = UV^{\frac{1}{2}}$.

The result of CMDS implementation in MATLAB for 50 nodes is shown in figure 2.

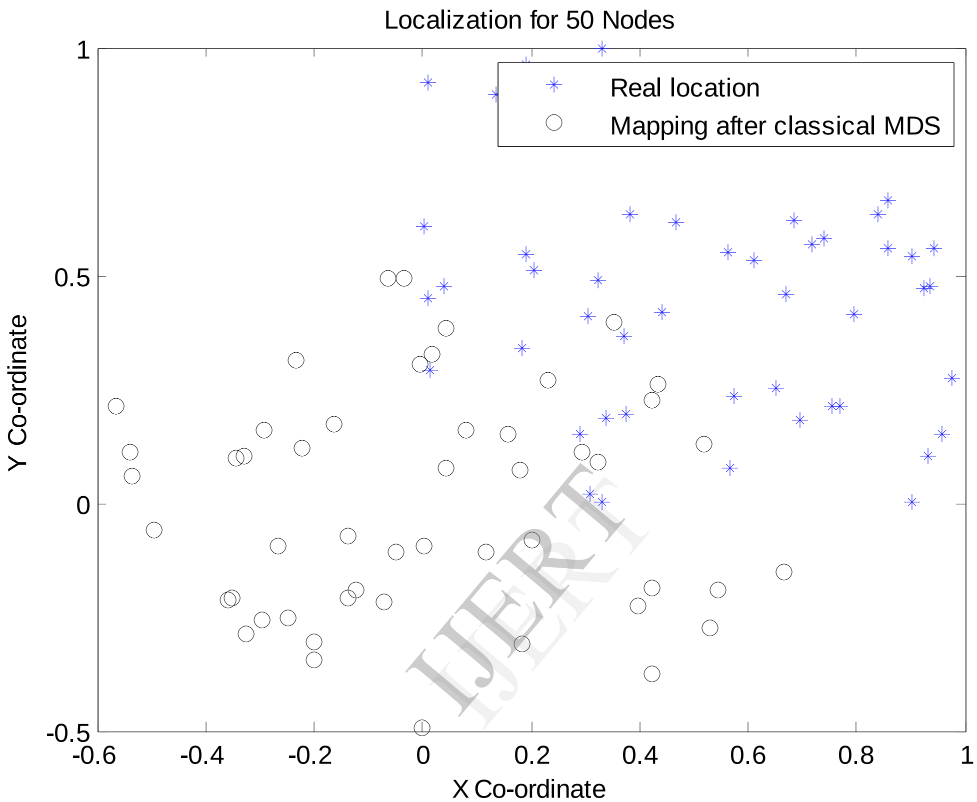

Figure 2.Localization of nodes after applying Classical MDS

The above graph shows that the CMDS technique gives an estimate of the position of the nodes. The degree of inaccuracy called stress is defined as

d_{ij} = distance between variables i and j in the configuration.

$$rawstress = \sum_{i,j} (d_{ij} - d_{ij}^{o})^2$$

Normalization Factor (sum of squared deviation from mean)

$$NF1 = \sum_{i,j} (d_{ij} - \bar{d})^2$$

$$Stress = \sqrt{\frac{rawstress}{NF1}}$$

The stress obtained after implementation of MDS technique is 0.3357. Although this value is less than 1, but it needs to be reduced to obtain better positioning of nodes.

Neural Network Implementation

NN is employed to effectively further reduce the *stress* in the location estimation problem. It provides better location estimation results than other approaches. Traditionally, the term "neural network" has been used to refer to a network of biological neurons. The modern definition of this term is an artificial construct whose behaviour is based on that of a network of artificial neurons. These neurons are connected together with weighted connections following a certain structure. Each neuron has an activation function that describes the relationship between the input and output of the neuron. Learning is viewed as the establishment of new connections between neurons or the modification of existing connections. Artificial Neural networks imitate functioning of the brain. They use non-algorithmic methods, which use parallel computing technique. Even though inter-neuron communication speed is quite slow for the brain, parallel processing allows it to analyze very complicated data in a short period of time. Neural networks learn directly from current examples.

The noisy position of nodes obtained after CMDS implementation is applied as input to Neural Network (NN) as shown in figure. 3 trained to give localization results. The NN selected is "newcf" shown in figure 4 and the results of CMDS for 50 nodes is applied to it that yields position of nodes. The implementation is done in MATLAB. Newcf network is a Cascaded- forward network consisting of N1 layers using DOTPROD weight function, NETSUM net input function, and the specified transfer function. The first layer has weight coming from the input. Each subsequent layer has weight coming from the input and all previous layers. All layers have biases.

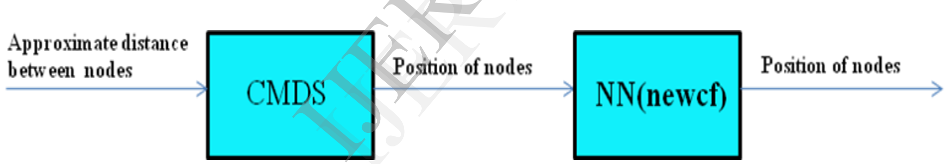

Figure 3

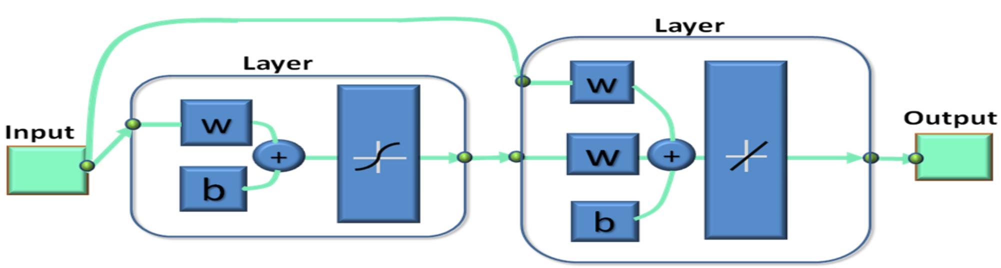

Figure 4

The localization obtained after NN implementation is shown in figure 5. This figure shows the position of original nodes, position after CMDS and position obtained after NN implementation.

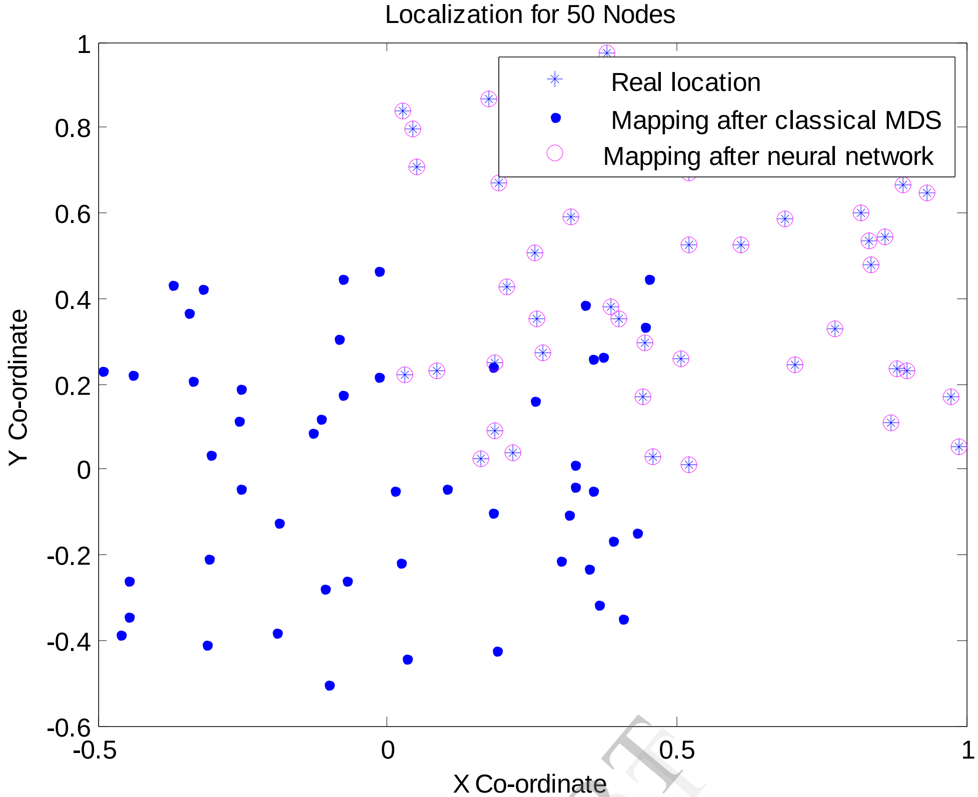

Figure 5 Localization after Neural Network

The stress value obtained after neural network implementation is 1.582339949091449e-015 which shows, the stress obtained has reduced drastically after NN implementation compared to Classical MDS technique.

5. Conclusion and future work

In emerging sensor network applications, localization in wireless sensor network is a recent area of research. Accurate localization or tracking of wireless device is a crucial requirement for many emerging location aware systems. Fields of application include search & research, medical care, intelligent transportation, location based billing, security, home automation, industrial monitoring and control, location -assisted gaming, and social networking. Requirement of its applications and availability of resources in WSNs need feasible localization algorithm with lower cost and higher accuracy. The result of NN localization implementation shows higher accuracy in node positioning. However require additional hardware, computational facility and memory that may be a deterrent where small size of sensor nodes is of prime importance. Some of the open problems in the area of localization are as follows [26]: Robust algorithm for mobile sensor networks, Attack the challenges of Information Asymmetry, Finding localization algorithm in three dimensional space.

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