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SENSOR PLACEMENT STRATEGIES: A REVIEW

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Abstract

In the aspect of engineering, sensor placement depends solely on applications area. There are instances where the placement of sensor is very easy, that is it needs no special method or mathematical prove and also there are cases where there is a lot of things to be put into consideration. There are a lot of work done in regards to placement of sensor for effective and efficient work, and also there are a lot of areas where sensor placement is applicable which are structural management, agriculture, housing, security. Military. In this review, a lot of research work that falls under this category were critically analysed and justification were done which would assist future researchers that wanted to dive in on the topic.

Introduction

Wireless sensor networks (WSNs) are made up of a huge amount of sensor nodes that are deployed based on certain statistical distribution over a certain geographical region of interest (GRoI). Each of these sensor nodes is equipped with several resource limited capabilities in terms of battery, computation and communication, and memory. However, when multiple sensor nodes are deployed in the GRoI, they assist one another to achieve tasks efficiently. Deploying a WSN has the advantage of low deployment cost and a less entangled communication system as compared to a wired system(Akyildiz et al., 2002; Chong & Kumar, 2003).

The real-time application of wireless sensor networks (WSNs) has gained popularity over the years in health care, intelligent monitoring, environmental studies, building and structures, and security. In these numerous applications, researches are continuing in the sensors' localization, routing, scalability, mobility, node deployment, sensitivity, coverage and lifetime, from which sensor node deployment plays a key role. Sensor deployment strategies are very crucial in achieving better quality of services to be rendered by the network while conserving energy in the respective areas of applications.

In WSNs, the four main issues to be taken into considerations for an optimal sensor placement are namely, **performance maximization, energy saving, cost maximization, and reliability maximization**(Mansouri et al., 2010). A couple of parameters are to be noted before and after the deployment of the WSNs in the GRoI in order to meet the desired performance goals. These parameters are: the sensing coverage of the nodes, node densities and the deployment model to be employed (Akbarzadeh et al., 2013a). It is necessary to streamline inter-sensor nodes communications to the sink in order to cover all areas and get all nodes connected. Sensor types determine the sensing range and for a particular application, a sensor should be carefully chosen to have an effective performance. To have a better coverage in the GRoI, a uniform density of sensor nodes is expected per square meters. The deployment strategies of sensor nodes are summarily under three major categories, deterministic, non-deterministic and semi-deterministic(Sergiou & Vassiliou, 2012).

The strategy to be employed in sensor placement is dependent on the application of the distributed sensor network (DSN). Grid placement is a deterministic approach where the nodes are strictly placed on the line of a grid. Semi-deterministic is also known as biased random placement, where the GRoI is deterministic but the distribution of the area is random which makes it non-deterministic. The non-deterministic placement is also known as stochastic placement whether the placement is either random (uniform) or simple diffusion based. The non-deterministic placement is a very realistic approach and an easy to use method(Pratibha. R. Biradar et al., 2015). Few other deployment strategies are probability distribution based and distribution free strategies.

The scope of this review paper is on the optimal sensor node deployment in WSNs for various applications such as in health monitoring, environmental monitoring, and intelligent monitoring (of human, animals and vehicles). While comparing a number of articles based on their strengths and limitations, optimal sensor placement strategies can be categorized as either static placement, optimization as at the time of operation of the sensor nodes. The aim of this work is to ease the selection of an appropriate strategy for a particular application.

Reviewed works

(Osmani, 2009)focused on sweep coverage to deploy sensor nodes in strategic ways such that an optimal area coverage was achieved in the application of the method. In the sweep coverage, a number of sensor nodes were moved across a sensing field in a way that specified balance between the maximum detection rate and the minimum missed detections per unit area were balanced. They applied Fuzzy logic system (FLS) to the distributed sensor deployment problem to have each sensor make a fully distributed decision on its movement. The paper utilized the Fuzzy based Re-Deployment (FReD) algorithm and the Fuzzy sensor placement based on neighbour's state (FSPNS) algorithm to control the sensors movement in the GRoI. They assumed a two-dimensional sensor field as target area of surveillance with the dimension of (200*200m*m area) for the FReD algorithm and (300*300m*m area) for the FSPNS algorithm. Their work is applied on surveillance system.

(Balaji, 2016)focused their research work on sensor nodes deployment to enhance the intrusion detection of humans, animals or vehicles in the GRoI. Half-Normal Distribution based sensor deployment was adopted to perform this specific task. This distribution was applied to road monitoring as a barrier coverage (a timely yet not continuous monitoring). A Deterministic Boolean sensing model was utilized for a better network coverage by the sensing nodes and the movement detection node is employed in the GRoI, whereby intruding vehicles, humans, and animals are detected with the full network coverage [6]. In their work, the intruder's movement is calculated using Cartesian system [7, 8] with the GRoI being a rectangular area of two half disk areas per the intruder movement and sensing range and they estimated the intruder to be detected by at least a single sensor towards the target region before reaching a maximum permitted distance (D).

(Akbarzadeh et al., 2013b)proposed a probabilistic sensor model for the optimization of sensor placement with a line-of-sight-based coverage. They identified that the deterministic placement methods of sensors are overestimated and this further complicated the sensor placement problems as sensor network deployers have no means of ensuring a truly effective coverage in the GRoI. They followed a more flexible non-deterministic approach to optimize sensor placement using the topographic information of the terrain and probabilistic sensor modelling in three ways listed below:

i. The 3-D terrain information of the GRoI was taken into considerations by defining the environment with geographical information system (GIS).
ii. In contrast to the deterministic approach, their method gives room for constraints to be applied on the sensors (limited sensing range and angles).
iii. Instead of a binary coverage (classifying a point as covered or uncovered), the method applied is probabilistic in its coverage (distance and sensing angle-wise).

In their paper, they proposed a directional and probabilistic sensor model by comparing four sensor placement methods namely, the deterministic method as known in WSN, an adaptation of optimization with simulated annealing (SA), the limited-memory Broyden-Fletcher-Goldfarb-Shanno (L-BFGS) method, and the covariance matrix adaptation evolution strategy (CMA-ES). The CMA-ES optimization method was reported to have outperformed the three other methods while it was tested in the GRoI with the probabilistic sensor model.

(Castello et al., 2010)proposed an optimal sensor placement strategy for environmental monitoring using wireless sensor networks (WSNs). This is achieved by minimizing the variance of the spatial analysis based on randomly selected points representing the location of the sensor. These points will be assigned to randomly generated measurements according to the specified distribution. Use geostatistical analysis (classical variation and ordinary point kriging) for spatial analysis and use Monte Carlo analysis for optimization. **A simple example of measuring mercury in soil is illustrated in finding the optimal sensor placement using WSNs. It was shown through simulations that the minimum variation decreases as the Monte Carlo repetitions increase**.

(Clark et al., 2019)focused their research work on a greedy sensor placement with cost constraints. In industrial and commercial product design and scientific experiments, the problem of optimizing the placement of sensors under cost constraints will naturally arise. In their work, they considered relaxing the complete optimization formula for this problem, and then extended the mature QR-based greedy algorithm to the optimal sensor placement problem without cost constraints. The effectiveness of the algorithm has been proven in datasets related to facial recognition, weather science and fluid mechanics. The algorithm is scalable, and usually needs to identify sparse sensors with near-optimal reconstruction performance, while significantly reducing the total cost of sensors. It is found that the cost and error conditions vary from application to application, and are intuitively related to basic physics. A principle-based greedy sampling strategy was developed to formulate sensor placement optimization as a cost-constrained problem in an easy way. In addition, they introduced parameters that represent the balance between reconstruction quality and cost, so the cost error curve can be evaluated explicitly. The proposed simple algorithm structure is based on the modification of pivot QR decomposition, which provides an effective and scalable strategy for economical sensor placement in a wide range of scientific and engineering applications. The algorithm was tested on three different data sets: the eigensurface, weekly sea surface temperature data, and the vortex shedding of the fluid flowing around the cylinder. In all cases, this method can reduce the cost of the sensor, but at the expense of a small increase in reconstruction error. It also shows that regardless of whether it contains a cost function, data sets with slow singular value decay can be pre-processed using random linear combination of patterns rather than SVD-based rank reduction for better results. Random linear combination will greatly reduce the reconstruction error, unless the number of sensors used is very small. The proposed algorithm provides a method to place the sensor under cost constraints. This method can be applied in manufacturing, atmospheric detection, fluid flow detection and more. Specifically, the algorithm solves three key engineering design principles regarding sensor placement:

i. For a fixed budget of sensors, where are the best measurement location,
ii. What is the minimal number of sensor required to achieve a given reconstruction error, and
iii. How well can inaccessible regions be reconstructed in practise.

Depending on the application, one or all of these issues may be the central issue. The method of computable management introduced in this article provides a principle mathematical method to answer these questions.

(Agarwal et al., 2009)proposed an efficient sensor placement for surveillance problems. In their work, they follow a widely used method to cover the sensor, that is, they sample a limited set of points and then use a greedy algorithm to calculate the position of the sensor. Its purpose is to calculate the location of the smallest number of sensors covering a given area. An efficient random algorithm based on greedy method is proposed. In this article, a method based on reference points is proposed to place a group of sensors. The main contribution of this document is that a small number of reference points are sufficient to guide the position of the sensor. The measurement parameters used as the standard for measuring and comparing the performance of algorithms are as follows:

i. The number of visibility tests performed by the two algorithms is
ii. The number of reference points selected by the algorithm is
iii. The number of iterations required to obtain polygon coverage and
iv. The convergence relationship of the algorithm; in each iteration, the relationship between the total area just covered and the total area of the polygon is measured.

(Bai et al., 2006)in their paper proposed deploying wireless sensors to achieve both coverage and connectivity. In this article, they proposed and tested the asymptotic optimization of an implementation mode to achieve coverage and connectivity for all values of r_c/r_s. Where, r_c is the communication radius and r_s is the sensing radius. They also demonstrated optimizations to the previously proposed deployment model to achieve full coverage and 1-connectivity $r_c/r_s < \sqrt{3}$. Finally, according to the number of sensors required to provide coverage and connectivity, the efficiency of some common conventional deployment modes (such as square grids and triangular grids) is compared. Among the four conventional implementation modes considered, none is optimal for all values of r_c/r_s. More specifically the following is correct:

i. When $r_c/r_s \geq \sqrt{3}$, the triangle based pattern is optimal to achieve both coverage and connectivity. It provides 6-connectivity for this range of r_c/r_s.
ii. When $\sqrt{2} \leq\ r_c/r_s \leq \sqrt{3}$, the rhombus based pattern provides coverage and 4-connectivity, while requiring at most 21% more nodes than the optimal. This implies that for this range of r_c/r_s, coverage and 4-connectivity can be achieved by deploying less than 21% extra nodes, provided they are deployed in rhombus based pattern.
iii. When $1.1398 \leq\ r_c/r_s \leq \sqrt{2}$, the square grid pattern provides coverage and 4-connectivity, but the number of sensors it needs over the optimal start to increase sharply with decrease in the value of r_c/r_s. It suggests that using the square grid pattern may be expensive (requiring up to 60% more than optimal) when $r_c/r_s < 1.14$.
iv. For $r_c/r_s < 1.14$, hexagon pattern provides coverage and 3-connectivity. The number of nodes needed by the hexagon pattern remains constant for $1 \leq\ r_c/r_s \leq 1.14$, implying that the number of sensors it needs over optimal decreases in this range. At $r_c = r_s$, it needs 44% more nodes than the optimal. When $r_c/r_s < 1$, however, the number of sensors it needs over the optimal, starts to increase exponentially. The number of sensors needed by other regular patterns in this range of r_c/r_s, is only worse. The implication is that when $r_c/r_s < 1$, using the strip-based pattern over the other regular patterns of deployment can result in significant saving in the number of sensors needed.

(Bianco & Tisato, 2012)in their work proposed a sensor placement optimization in buildings and structures. In their work, four major problems identified by Horster and Lienhart were focused on. They are:

i. Maximizing coverage subject to the given number of sensors,
ii. Maximizing coverage subject to the maximum total price of the sensor array,
iii. Optimizing senor poses given fixed locations, and
iv. Minimizing the cost of the sensor array given a minimally required percentage of coverage.

In their experiments, they compared the performance of Greedy's algorithm and the proposed direct search (DS) algorithm with the best solution obtained by modeling the problem as a binary integer programming (BIP) problem. In order to solve the four problems under consideration, they proposed two different optimization-based algorithms: the first is used for discrete problem space, and the second is used for continuous space. The proposed algorithm is a direct search (DS)-based algorithm, which can approach the global optimal solution with reasonable time and memory consumption. From the obtained results and comparing the results with the existing greedy algorithms, the DS algorithm can improve the results of the approximate algorithms in the prior art.

(Bottino & Laurentini, 2008)proposed a nearly optimal sensor placement algorithm for boundary coverage. They proposed a new edge coverage sensor (EC) positioning technology. The algorithm is said to be progressive and converge towards the optimal solution. Complete the initial approximation provided by the Integer Coverage Algorithm (IEC), where each edge is fully observed by at least one sensor. At each step, a smaller number of sensors (specific to the polygon considered) are used to assess the quality of the current solution, and a set of rules is provided to perform local optimization to reduce computational load. The algorithm has been implemented and tests on hundreds of random polygons show that the solution it provides is very close to the lower limit and usually matches the lower limit and then reaches a suboptimal or optimal state. In addition, the approximate initial solution provided by the IEC algorithm is on average close to the optimal value. The adjusted lower limit can also be used to test other CE sensor placement algorithms. The runtime allows you to process polygons with hundreds of sides, which seems sufficient for many use cases. They further improved the algorithm, taking into account the scope of implementation and testing and incident limitations. His method aims to balance the average calculation time and the quality of the solution. This requires an incremental algorithm that can gradually improve the initial solution. In order to make this stepwise algorithm feasible, the following conditions need to be met:

i. a technique for evaluating the quality of the current approximate solution,

ii. an algorithm able to refine locally the solution to reduce the computational burden.

The difference in its focus is that it aims to balance computation time and focus optimization. The key element of the algorithm are:

i. IECA, the integer edge covering algorithm, which provides a starting solution that can be locally refined;
ii. LBA, the algorithm that provides a lower bound for the number of sensors, specific of the polygon considered, and allows to evaluate the quality of the solution; and
iii. INDIVA, the algorithm that allows to refine locally the integer edge cover, and thus reduces computations.

In order to see whether his method leads to an effective practical algorithm, tests have been conducted on approximately 400 polygons of various categories and with different numbers of sides. The results obtained can be considered well, especially in terms of approaching optimality. It only takes a few steps to get a solution that is very close to or consistent with the lower limit. In terms of execution time, the algorithm can easily handle polygons with dozens of sides. For larger polygons, the bottleneck is setting the coverage algorithm, which is part of the integer coverage algorithm. However, tests have shown that for this particular ensemble structure, the time-saving greedy solution is equal to or very close to the best exact integer coverage solution.
(Casillas et al., 2013)proposed an optimal sensor placement for leak location in water distribution networks (WDNs) using genetic algorithm (GA). The sensor position problem is expressed as an integer optimization problem. The optimization criterion is to minimize the number of inseparable leaks based on the introduced separability criterion. This method is used in conjunction with a projection-based leak location scheme, but can easily be applied to any other sensitivity-based insulation scheme. The first semi-exhaustive search method is proposed, which searches for the best configuration and is based on a lazy evaluation mechanism to reduce computational cost. However, for most practical situations, the calculations are still too rough. Therefore, they proposed a method of using genetic algorithms to solve optimization problems. Genetic

algorithm can solve the large problems of nonlinear integer properties very well. They found that this method allows them to find a solution that is close to the best in an effective way.

They also emphasized that the change in leakage is affecting the best sensor location found by the GA algorithm, so post-processing analysis is needed to solve this problem. Finally, three improvements are proposed to avoid any post-processing and improve the robustness of GA-based sensor placement. Experiments were conducted in two types of networks to compare the different methods proposed in this document. They show the relevance of a powerful method based on GA.

(Chen & Lin, 2013)proposed a low cost anchor placement strategy for range-free localization problems in wireless sensor networks. In their research, they proposed a low-cost but effective anchor node placement strategy for the non-distance location problem of WSN in a very dangerous area that is not easy to access that is hazardous area. The proposed method uses as few as two anchor nodes to estimate the location of unknown sensors. In the study, all anchor nodes are installed at the boundary of the monitored area at equal distances. Based on the minimum number of hops to the anchor node, the distance between each unknown sensor and the anchor node is estimated. The position of the unknown sensor depends on the number of anchor nodes and is obtained by applying the bidirectional positioning method (BLM) or the least squares multi-directional positioning method (LSMLM). Their simulation results show that the strategy is effective. When LSMLM-16 is used and the communication range (CR) is greater than 50 meters, the average range error of the unknown sensor is as low as 0.15. BLM only uses two anchor nodes to locate unknown sensors. Although BLM is attractive due to its low installation cost and communication overhead, its range error is slightly higher (generally between 0.4 and 0.5). Therefore, it is suitable for coarse-grained positioning. This research shows that adding more anchor nodes can reduce the error rate. The experiments also show that as the number of anchor nodes increases, the marginal effect of adding anchor nodes to reduce the error rate decreases. In LSMLM, the error rate converges as the number of anchor points approaches 16. They compared their proposed positioning scheme with the established DV-Hop method. The simulation results show that this scheme is superior to the

DV-Hop method in terms of positioning accuracy and communication cost. Although both BLM and LSMLM apply to the square area monitored in this study, the same algorithm can be used for rectangular areas without modification.

(Chmielewski et al., 2002)in their article, considered the design of data-reconciliation enhanced sensor networks. The current state-of-the-art design methods were reviewed and some of their limitations were highlighted. They proposed another alternative to the reconciliation problem, but its equivalence is that its main advantage is the ability to exchange measured and unmeasured variables without having to change the structure or size of the problem. In addition, the non-linear equality and inequality constraints of the displayed sensor optimal position problem are proved to be completely equivalent to a set of convex inequality constraints in the form of LMI conditions. The main contribution of this work is to redesign the optimal position of the sensor so that the established search algorithm can be used to effectively determine its global solution. Using the proposed method, the minimum cost associated with imposing physically important performance standards can be quickly and easily calculated. As a result, the control and monitoring system designers are closer to establishing a strict trade-off curve between cost and performance.

(Du et al., 2015) In their work, study an optimal sensor placement scheme to measure the wind distribution over a large urban reservoir with a limited number of wind sensors. Unlike existing sensor placement solutions where the target phenomenon is a Gaussian process, this study measures wind which inherently exhibits a strong non-Gaussian annual distribution. Taking advantage of the local characteristics of the monsoon, they divide the year into different monsoon seasons, each following a unique distribution. They also use computational fluid dynamics to understand the spatial correlation of wind in the presence of surrounding buildings. The sensor location output is the most useful set of locations where the wind sensors are deployed. Based on these readings, they can accurately predict the wind across the entire surface of the reservoir in real time. Finally, ten (10) wind sensors are implemented around or above the water surface of the urban reservoir. The results of the field measurements over 3 months show that the proposed sensor location and the space prediction method can provide an accurate wind measurement, and its performance is better than the method based on the latest Gaussian model or based on interpolation.

(Huang & Tseng, 2005) In their paper, proposed solutions to two versions of the coverage problem in surveillance and monitoring, namely k-UC and k-NC, in a wireless sensor network. They model the coverage problem as a decision problem, the purpose of which is to determine whether each location in the target detection area is adequately covered. His solution is not based on determining the coverage of each location, but on verifying the perimeter of the detection range of each sensor. Although this question may seem difficult at first glance, the proposed solution can give an exact answer in O(ndlog d) time. Using the proposed technology, they also discussed various applications of their results (finding areas with insufficient coverage and saving power) and extensions (scenes with hot spots and irregular detection ranges).

(Salajegheh, 2013)Developed a methodology for sensor placement optimization based on a new geometrical viewpoint. The view of this method for "Optimal Sensor Placement" (OSP) is the projection of elliptical noise in the response space. Based on this point of view, six simple advance algorithms are introduced. Elliptical noise adjusted by the filter factor is called equivalent elliptical noise. Use the response records of the optimal sensor location obtained from the algorithm in two states to detect damage, one state is to use elliptical noise before regularization and the other is to use the equivalent elliptical noise based on the geometric point of view in algorithm. The results show that algorithm A, based on the elliptical noise projection rule on the surface of the state 2 response space is the best algorithm, the damage detection is more accurate, and the number of elements healthy is wrongly detected and the damage is minor. Therefore, the geometric perspective can be applied to the OSP problem and regularized using specific filter factors to obtain the best location effect. The numerical examples show that this method is accurate and efficient.

(Lin & Chiu, 2005)proposed a near optimal sensor placement algorithm to achieve complete coverage/discrimination in sensor networks. In their work, they developed a robust and scalable algorithm to deal with the sensor placement problem at the target location under the constraints of cost and comprehensive coverage. For any sensor field, the problem is NP-complete. The grid-based location scheme is adopted, and the sensor location problem is formulated as a combined optimization problem to minimize the maximum distance error in the sensor field under constrained conditions. The proposed algorithm is based on the simulated annealing method. They first formulated the problem as a minimum-maximum mathematical optimization model with recognition accuracy as the goal. Then, a simulated annealing based algorithm was developed to solve the optimization problem. The experimental results show that the algorithm can effectively obtain high-quality solutions. Furthermore, the proposed algorithm is very efficient, scalable and robust.

(Liu et al., 2013)proposed a work on Hierarchical spatial clustering in multi-hop wireless sensor networks. In this article, they considered the problem of spatial clustering for the collection of approximate data, which is feasible and energy efficient for environmental monitoring applications. Spatial clustering aims to group highly related sensor nodes into the same cluster so that representative data can be reported in turn in the future. Through an exhaustive investigation of the real environment dataset, they observed a strong spatio-temporal correlation and defined a new similarity metric to verify the similarity between two sensor nodes, taking into account their detection at the same time Size and trend of the readings. Using this metric, they proposed a clustering algorithm called Hierarchical Spatial Clustering (HSC) to cluster the most similar sensor nodes in a distributed manner. HSC runs on a predesigned Data Collection Tree (DCT), thus eliminating some additional requirements, such as global network topology information and strict time synchronization. They used the coefficients of the autoregressive model (AR) as an important grouping parameter, and designed a new similarity measure that took into account both amplitude similarity and trend similarity. Using this metric, the proposed HSC algorithm groups the most similar sensor nodes in a distributed manner based on DCT. Extensive simulations were carried out using typical data sets, and the results showed that the quality of HSC clustering was higher than that of the three alternative algorithms. In addition, the simulation based on the approximate data collection scheme proves the efficiency and accuracy of our algorithm in data collection. A large number of simulation results based on the real world and comprehensive data sets show that, compared with other algorithms, HSC performs well in terms of clustering quality. Also, compared to other algorithms, the approximate data collection scheme combined with HSC can reduce more communication overhead while simultaneously producing moderate data errors.

(Rao et al., 2017)proposed a practical deployment of an in-field wireless sensor network in date palm orchard. This article introduces experience in deploying an experimental sensor network in the field, which can provide real-time monitoring in a 10-year-old date palm orchard. Taking into account the spatial variability of multiple soil variables that determine growth, the sub-region of the sensor location is determined by delimiting the orchard in each monitoring area (group). Then, according to the accuracy requirements of the data, calculate the specific number of sensors required. By combining the tree number with the coefficient of variation of the soil variables that determine the growth of the monitoring area, the sensors are distributed in the target orchard. Finally, the network connection is made by integrating the intensity distribution of the received wireless signal, the design of the monitoring area, and the number of sensors required. Presented and discussed some data from implemented wireless sensor networks.

(Khosrowshahi & Shakeri, 2018)proposed a Relay Node Placement for Connectivity Restoration in Wireless Sensor Networks Using Genetic Algorithms. In their work, they solved the problem of network partitioning, in which when multiple nodes fail due to catastrophic events such as explosions, the network will be divided into several separate segments. Re-establish the connection by introducing multiple relays. This problem is rephrased as the Steiner Tree Problem (STP); whose purpose is to find the smallest Steiner Point (SP) of the relay node (RN) location. Facing the NP-difficult optimization problem, they developed a genetic algorithm (GA) to iteratively reduce the number of repeaters and determine their positions at the same time. The main work in three areas is summarized as follows:

i. A new methodology based on meta-heuristic algorithms (here, GA) is proposed for the first time for connectivity restoration in multiple-node failures.
ii. The superiority of the proposed GA in reducing the number of relays is demonstrated against the best existing work, especially for large scale damage.

iii. Having belonged to the class of meta-heuristic algorithms, the proposed GA is capable of orienting the search towards optimizing some quality of service (QoS) indicators (other than minimizing the number of RNs) if being supplied with appropriate objective functions.

(Dhillon & Chakrabarty, 2003)formulated an optimization problem on sensor placement, wherein a minimum number of sensors are deployed to provide sufficient coverage of the sensor field. This approach provides a unique "minimized" view of a distributed sensor network, where the minimum number of sensors is implemented and the sensor transmits / reports the least amount of sensor data. They proposed a polynomial time algorithm to optimize the number of sensors and determine their location to support this minimalist sensor network. The proposed algorithm solves the coverage optimization problem under the limitations of inaccurate detection and terrain characteristics. The priority coverage of the grid points (based on relative security measures and tactical importance) was also modelled. Several case studies (such as obstacle sensor fields and priority coverage) show that the proposed algorithm is significantly better than random and uniform sensor placement.

(Shen et al., 2018)proposed a research work on optimizing the positioning of soil moisture monitoring sensors in winter wheat fields. Collecting accurate real-time soil moisture data at crop roots is the foundation of an automated precision irrigation system. Soil Moisture Sensors (SMS) have long been used to monitor soil moisture (SWC) in crop fields. However, there are currently no accepted guidelines for determining the optimal number and location of soil moisture sensors in the soil profile. In order to study the proper location to install the soil moisture sensor in the soil profile, the researchers conducted six years of field tests in the North China Plain (NCP). During the six growing seasons of winter wheat, gravimetric analysis was used to measure soil water content every 7 to 10 days, and the soil core method was used to measure root distribution during the critical period of winter wheat growth. The results of the analysis of experimental data show that SWCs of different depths have a high linear correlation. In addition, the value of the correlation coefficient decreases as the depth of the soil increases. The coefficient of variation (CV) of SWC in the surface layer is higher than in the deep layer (winter wheat depths are 0-40 cm, 0-60 cm and 0-100 cm in the early, middle and end of winter wheat), respectively; the roots of wheat are distributed mainly in the surface layer. Based on the analysis of CV of SWC and root distribution, during the period from sowing to the recovery period (early winter wheat), it was determined that the depth of the planned wet layer was 0-40 cm, 0 -60 cm and 0-100 cm), they return respectively to the green and binding stages (the intermediate stage of winter wheat) and enter the maturity stage (the last stage of winter wheat). The correlation and R cluster analysis of the SWC of different layers in the soil profile indicated that the SMS should be installed 10 and 30 cm below the soil surface during the winter wheat growing season. The SWC can be used to build linear regression models at depths of 10 and 30 cm to predict the total average SWC in the soil profile. The verification results show that the developed model provides a reliable estimate of the total average SWC of the planned wetting zone. In summary, the study shows that the proper location for the soil moisture sensor is at a depth of 10 to 30 cm below the soil surface.

(Visalini et al., 2019)presented a Sensor Placement Algorithm with Range Constraints for Precision Agriculture (SPARC). They first proved that the optimal sensor placement problem with range constraints is NP-difficult and cannot be solved with existing tools. In order to overcome this problem, a two-stage solution technology called the Distance-Limited Sensor Placement Algorithm was proposed. In the first stage, the sensor is placed in the best position to reduce the estimation error, and in the second stage, the sensor position that violates the range limit is projected into the feasible space. The two-step method solves the computational problem. The WSN sensor node used in the research is built on Arduino and interfaced with soil moisture (LM393), temperature, and humidity sensor (DTH22). The WSN implemented using off-the-shelf sensors verified the results, but the accuracy is not guaranteed. The proposed SPARC can place the sensor within the range limit. The results show that, compared with the optimal sensor problem studied in the literature, the distance limitation requires more sensors. SPARC's optimal loss calculation is a future research prospect.

(Arbesser-Rastburg & Fuchs-Hanusch, 2020)in their paper, proposed a novel approach in water loss research combining two different topics: The optimal placement of pressure sensors to localize leaks in water distribution systems and

Serious Gaming-games that are not only entertaining but that are also serving another purpose was proposed. The goal is to create a web interface through which players can place sensors on the water distribution system model to improve the location of these sensors after evaluating them with the appropriate algorithms. Players must pursue two goals of the game: to reach a specific net coverage area without using more than the maximum number of sensors. To this end, the existing sensor optimal placement algorithm is extended and implemented together with two hydraulic models obtained from the literature. The resulting "serious games" were then tested and rated in a case study. The results show that human participants can obtain a solution similar to the network coverage obtained through optimization in a short time. In addition, it also shows that the ideal sensor placement problem during serious gaming can inspire gamers to get better and better results while providing them with a pleasant gaming experience.

(An et al., 2015) In their paper; Effective sensor deployment based on field information coverage in precision agriculture, proposed a novel notion of information coverage. The information being sensed in this regard is the water storage capacity of the locations, which is closely associated with the apparent soil electrical conductivity (ECa). Because the field information changes spatially, this necessitate the needs to deploy some senor nodes such that the water content in the soil can be monitored and the optimum quality of irrigation water can be derived. Soil moisture and temperature sensor nodes the eKo eS 1101 watermark sensor nodes are used to monitor soil moisture and temperature deployed for this function in the selected locations. Based on this concept, they divided the field into multiple graphs and selected some graphs to deploy sensor nodes so that the information from the covered fields can meet the requirements. Regardless of communication, two effective polynomial time algorithms are developed to determine the display position of the drawing node with information coverage rate 1 and coverage rate q respectively. In addition, a theoretical limitation is provided for the proposed algorithm. Next, a polynomial time algorithm was developed to determine the deployment location of relay nodes, thereby achieving the minimum number of relay nodes. Finally, the information coverage rate of the WSN-based precision agricultural irrigation system proposed in the project was applied. A large number of experimental results show that the main compensation for the influencing factors in sensor deployment and the significant improvement of the proposed method.

Conclusion

In this research work, a review on Wireless Sensor Networks (WSN) placement strategies was conducted. Wireless sensor networks consist of small nodes with sensing, computation, and wireless communications capabilities. A lot of work that focused on sensor node irrespective of their area of application were reviewed so that researchers planning to dwell in the area will know phases the work has passed through and would be able to focus on the issues arising from the previous established researches.

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