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A STUDY OF MINIMAL EXPOSURE PROBLEMS AND COMPARATIVE ANALYSIS OF VARIOUS PROPOSED MODELS FOR WSNs

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ABSTRACT:-

Wireless sensor networks are made up of networking capabilities with embedded sensors. The applications of WSN are ranging from commercial, automation and military filed. Micro fabrication and Embedded sensor programming models have been joined and produced the massively scale sensor deployments. The main objective of the sensor deployment is to sense the physical environment and to track the objects in the field. To extract the reliable out-turn from the wireless sensor networks, the enough coverage region is needed. Minimal Exposure Problem deals with the coverage of objects on the sensor deployment field. Minimal Exposure Path gives the better coverage path of sensor networks. This path is used to detect and monitor an object and its motion for the observer. The low quality coverage affects the lifetime of sensor networks. This coverage calculation yields a best case and worst case object tracking measurements. In this paper the various solutions and parameters of different authors are studied. Optimization techniques are used to solve many research challenges that have formulated during the implementation phase. With the idea of solving this implementation complication various proposed optimization problems are formulated.

In most of the papers, the minimal exposure values between two points are identified. In some papers the minimal and maximal exposure path along road network are observed. The proposed methods are compared with traditional methods and also the comparative analyses are studied. The high intensity sensing functions and rejoins of sensor deployment fields are measured effectively. This papers aims to bring the study and analysis of various mathematical inspired models which are used to solve exposure problems in sensor deployment field.

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KEYWORDS:-

MINIMAL EXPOSURE PROBLEM (MEP), BIOLOGICAL MODELS, PHYSARUM BEHAVIOR, OPTIMIZATION TECHNIQUES, HYBRID GENETIC ALGORITHMS & PARTICLE SWARM OPTIMIZATION TECHNIQUES

I. INTRODUCTION:-

Wireless sensor networks are distributed networks with embedded sensors along with temp, pressure and sound. The applications of sensor networks in the field of IOT are getting more attraction recently. The most widely used sensor networks applications are object detection and object tracking. For this purpose only the sensor networks are deployed with high range coverage. All the nodes in the network are shared a common infrastructure. The main research challenge for the sensor network is the quality range coverage and calculation. The efficient coverage gives the good output to the sensor nodes. Minimal exposure problem is the recent challenging area to be addressed and solved recently. Many algorithms have been proposed in recent initiatives. This paper is classified as 4 sections. Section 1 is addressed about the overview of Minimal Exposure Problem. The sections 2 & 3 are studied and represented with high quality understanding of the biological models (problem formulation models) proposed by researchers. Followed by the section 4 is presented with the solutions and performance results of different methodologies and algorithms. Finally the section 5 has given the conclusion and future proposed works that will be carried out.

II. PROBLEM FORMULATION MODLES:-

1. BIOLOGY – BASED MODELS [1]:-

a) Problem Statement:

In this paper the MEP is formally defined as the ability to detect the object sensor deployment field as coverage plays a major role in sensor network output [1]

b) Focus of this Paper:

MEP is divided into two categories. One is between

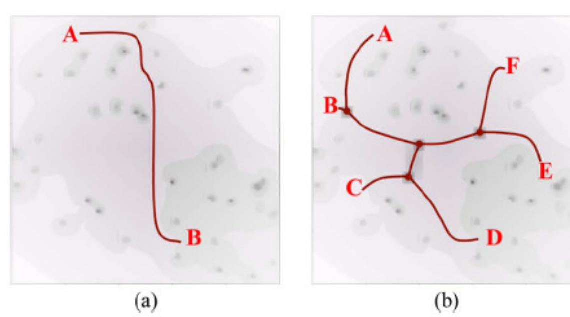

Fig. 1. Examples of minimal exposure problems in a sensor deployment field, where the darker regions have greater exposure values. (a) The minimal exposure path problem with two PoIs. (b) The minimal exposure road-network problem with multiple PoIs.

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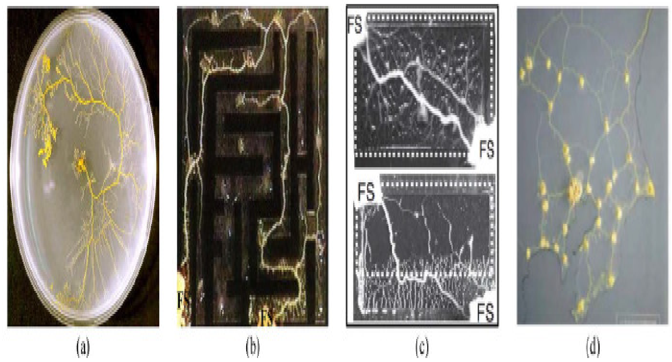

the two points of interests and another one is between multiple points of interests. Normally, the researchers have been presented the biological inspired algorithms as a NP hard problem which have used widely in scientific research. In that paper the biological model is clearly defined as ***"A physarum is a living organism inspired by biological behaviors which has a tubular shape body to transport nutrients and signals***" [1]

Fig 2. Photographs of Physarum[1]

c) Maze solving behavior of Physarum: (Great Feature):

The food is distributed patchily to physarum so that the tubular network body connects the sources in foraging fashion. Physarum's are photophoic. They are finding the FS's in the darkness of deployed two FS's. Network finding ability is applied to the organism in the illuminated homogeneous light field [1].

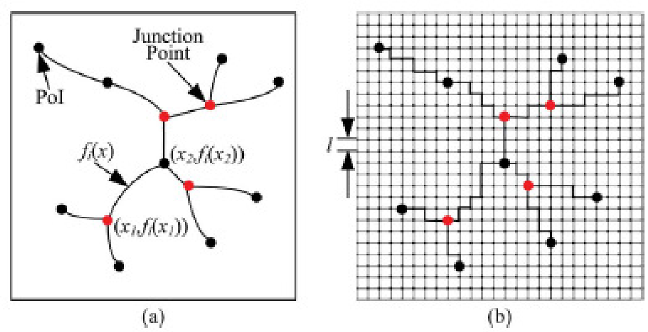

Fig. 3. (a) A schematic illustration of road-network. (b) The approximation of the minimal exposure road-network in a weighted grid.

d) Great Work:

The author of the paper exposed the Physarum road network formation solution that is implemented for **Tokyo Rail System** design. The **Physarum Optimization (PO)** was proposed to find the road network which was connecting multiple POIs [1]. Also the author proposed the **Edge Cutting Scheme** using Proportional Threshold to achieve the minimal exposure path road networks [1]. The basic problem

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formulation models have been studied such as Sensitivity Model, Intensity Function, Path Exposure & Road Network Exposure [1].

e) Study of the behavior and computational model of Physarum[1]

Step 1:- Initial Mesh Graph Formation G = (V, E) with junction nodes

Step 2:- Assuming two properties of physarum thickness for tubular path and pressure junction nodes (Nutrition flow)

Step 3:- Inflow and Outflow will be balanced on physarum's core based on the conservation law of flux

Step 4:- if the tubular thicker, it's consumed high food. If thinner it contains low flow of food

Step 5:- If the tubular path is getting thinner, it will be considered as dying.

f) Constraints of Physarum optimization

In their optimization, the physarum has encountered the following four constraints [1]

- ✓ Law of flux. For conservation, R1
- ✓ Inflow and outflow adjustment R2
- ✓ Tubular path adjustment R3
- ✓ Thin tube path elimination R4
- ✓ Thickness indicates the fulfillment of food sources
- ✓ Thin indicates the emptiness of food resources
- ✓ Thin and thickness should be balanced

g) The conservation law of flux

R1 is used to establish a connection between physarum's core and food resources. The R2 and R3 create a positive feedback which maintains the inflow and outflow of the nutrition between the tubular paths. R4 is used to produce the thickness and thinness of the tubular body.

h) Summary of Physarum Optimization:

The author of paper summarized the proposed method in the following lines

The tubular structure has the morphogenesis property. Based on this property the network finding process is carried out. This model is represented as randomly meshed lattice in which c is assumed as a physarum core and the set of food sources are considered as T = t1,t2… tT

2. PHYSARUM– BASED MODELS [2]:-

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a) Problem Statement:

In this paper, the authors are presented a cellular computing model in association with physarum for solving Steiner tree problem first. Then the same is applied to solve minimal exposure problem [2].

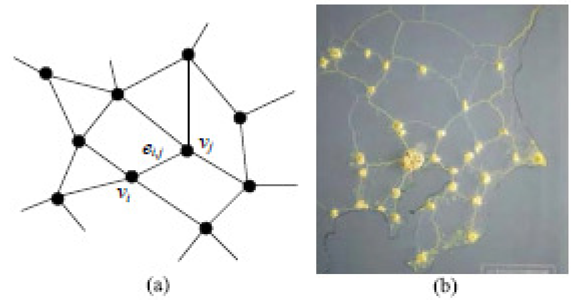

Fig 4: Physarum Representation

b) Focus of this Paper:

The intention of this proposed work is finding solution to Steiner tree problem and presented the work to the MEP. The aim for solving STP is to establish a road network with least coverage of given two Point of Interests (POI)[2].

c) All Sensor Intensity Function:-

In this paper, All Sensor Intensity Functions are used to calculate the road network of two POI's on a weighted grid. For a given point T, the sensing intensity is calculated using the assumptions I(T) = SIF[2].

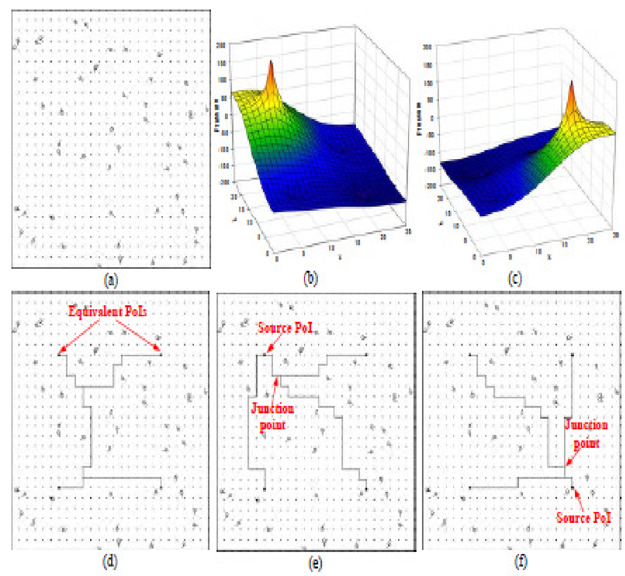

Fig 5 : Physarum Representation on grids

d) Road Network Exposure:

The authors of the paper are used to calculate minimal exposure road network with help of the parameters R and E. Here R represents Road Network and E abbreviates Exposure to the network [2].

e) Great Work:

The output area is identified as square with divided fine grids. In which the target moves on. The minimal exposure road network is found using a graph designed with edges, vertexes, weights and neighbor vertexes. Finally the Steiner tree path is found which is considered to be equal to the minimal exposure path later.

3. HYBRID GENETIC ALGORITHM BASED MODELS [3]:-

a) Problem Statement:

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MEP is described as the indicator of good quality coverage. This is used to monitor the object with an arbitrary fashion. The authors of the paper are clearly narrated that the traditional grid based method and voronoi diagram based methods are not efficient on processing heterogeneous sensor network deployment field. So they have come with a solution called numerical functional extreme models. To achieve the accurate results, the hybrid genetic algorithm based models were proposed with more collections of experiments. And also the authors stated that, the proposed models are given high accuracy solutions.

b) Great work done in this paper:

New Genetic algorithm Design Phase:

The authors of the paper were proposed cross over operator, a local search scheme, & upside down operator. And they have named the new algorithm as HGA-NFE. The major contributions of the models are as follows,

1. Designing a NFE model for MEP is yielded a global MEP Model
2. The NFE model was applied to different cases such as all sensor field intensity model, maximum sensor intensity function, heterogeneous sensor networks and large scale sensor node networks.
3. Minimal Exposure Path as functional mathematical models

c) Models developed:

In this paper, the following mathematical models are proposed.

1. Classical Mathematical Models – Failed because of hardness in retrieving derivatives.
2. An effective hybrid genetic algorithms – Stochastic optimization methods, evolutionary algorithms
3. Normally GA consists of the sample set
4. The fitness values are considered as the performance indicators
5. The cross over operators are used upside down operators

4. MAXIMUM AND MINIMUM PATH EXPOSURE [4]:-

a) Problem Statement: Closed Solution

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The author of the paper was proposed an efficient localized algorithm for single sensor optimal solution by variational calculus. In the proposed theorem I , they authors derived boundary condition with Euler's theorem. In theorem II , the sensor sensitivity function was derived to find out the distance between sensors location s and p. In theorem III, the minimal exposure path between two points of interests was carried out.

```
Initialize(Grid G)
    Start.Cost = 0
    Start.Visited = FALSE
    Start.Parent = Ø
    For each node i in G that is not Start
        i.Cost = ∞
        i.Visited = FALSE
        i.Parent = Ø
```

```
Search(Grid G)
    Initialize(G)
    while Finish.Visited = FALSE
        Let i be the unvisited node with the lowest cost.
        i.Visited = TRUE
        For each neighbor j of i
            if i.Cost + Exposure(i, j) < j.Cost
                j.Cost = i.Cost + Exposure(i, j)
                j.Parent = i
```

b) Multiple Solutions:

A grid based localized approximation method was proposed with multiple sensors to find the bounded errors. This method was applied with the following assumptions.

1. Forwarding messages to compute the shortest path
2. Sensor nodes are storing, receiving and forwarding topological information's
3. Voronoi diagram based models are used to reduce the computation overhead
4. Weights are applied
5. Forward messages and search messages are used

```
Search*(Grid G)
    Initialize(G)
    while Finish.Visited = FALSE
        Let i be the unvisited node with the lowest cost.
        if i is not on known Voronoi Border
            i.Visited = TRUE
            For each neighbor j of i
                if i.Cost + Exposure(i, j) < j.Cost
                    j.Cost = i.Cost+Exposure(i, j)
            j.Parent = I
```

```
GetBestPotentialNode(Grid G)
    BestP = ∞
    Best = Ø
    For each node i in G
        P = i.Cost + Worst(i, Finish)
        if (P < BestP)
            BestP = P
            Best = i
    return Best
```

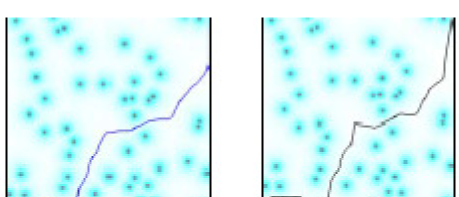
```
Worst(Node N, Node Dest)
    WorstValue = 0
    For each sensor i in S
        if Exposure(i, Dest) > WorstValue
            WorstValue = Exposure(i, Dest)
    return WorstValue

ForwardMessage(Node N, SensorNetwork S)
    if N is closest to destination
        SearchMessage(Finish, S)
    else
        Next = GetBestHeuristicNeighbor(N)
        ForwardMessage(Next, S)
```

```
SearchMessage(Node N, SensorNetwork S)
    if N is closest to destination
        Let G be a Voronoi-Based Grid
        Search*(G)
        Next = GetBestPotentialNode(G, S)
        if Next ≠ Ø
            ForwardMessage(Next, S)
    else
        Next = GetBestHeuristicNeighbor(N)
        SearchMessage(Next, S)
```

c) Multiple Solutions:

The authors are also carried out the maximal exposure also using the following parameters. Maximum length, maximum delay time, maximal velocity and maximum upper bound.



Comparison of minimal exposure paths calculated from the centralized algorithm (*left*) and the localized algorithm (*right*) using a sensor network with 50 sensors and an exposure model of $(1/d^2)$.

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Fig 7

III. PROPOSED METHODS:-

1. BIOLOGY – BASED MODELS [1]:-

a) Edge Cutting Scheme:-

First Challenge:-

Based on the **pressure fluctuation** the proposed scheme was implemented. The authors of the paper also have described that, if the edges of the grid were deleted the pressure fluctuation was increased gradually. Due to the high amplitude, the pressure fluctuation was increased and it was maintained properly by adjusting the P_i and P_j Values.

Second Challenge:-

The **Judgment of small conductivity** of the edges is the traditional intuitive methods of applying threshold. In this challenge the two types of threshold levels were applied in this paper. The first one is dynamic threshold T_1 and the second is proportional threshold T_2. The T_1 is expressed as an increasing function F_1 at t. The second one is proportional threshold T_2 used for maintaining the cut edges.

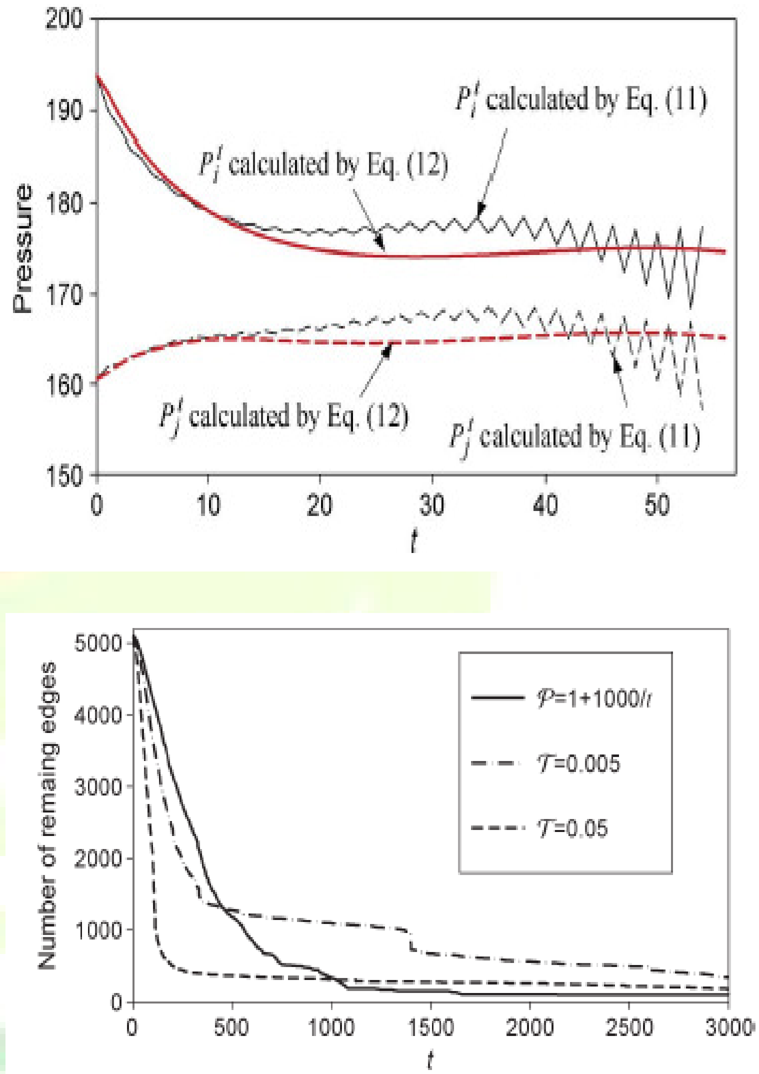

Fig 8:- Pressure Fluctuations

b) Feedback Adjustment Scheme:-

The positive feedback system was proposed based the conductivity of flow of flux. The parameters were adjusted as per experiments conducted and also the effects were measured properly.

The parameter measures are assumed as p and ∞ respectively. The variation of ∞ is identified and also studied as increased effect of the convergence. The large volume of ∞ is indicating the exponential growth

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with large value. If the p and ∞ are relatively high, then the proposed optimization solution is failed to find the road networks.

2. PHYSARUM– BASED MODELS [2]:-

a) Mathematical Proposed Model:

Based on the morphogenesis tubular structure and protoplasmic flow, the tubular structure is defined. The randomly meshed topology was constructed initially. The conductivity values are calculated and the formula was derived. As per the formula, the expansion of tubes and constriction of tubes were identified.

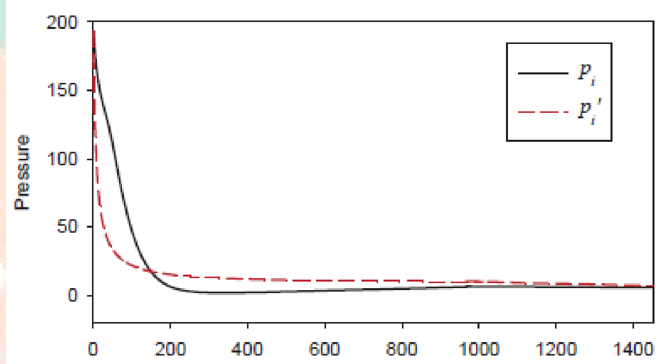

Fig 9 :- Pressure Representation

The main steps involved in this optimization are as follows

- Initialize the weight of the edges
- Calculating the exposure of each edges
- Feedback driven evaluation is carried out
- The variation of pressure was identified
- Edge Cutting Scheme is also used

b) Algorithm:-

Source sink based physarum models have been considered. The authors of the papers were found the minimal exposure road network with three point if interests. The following major steps are used as algorithm

Steps:-

- V1, V2 & V3 target points are fixed.
- The iteration with n times are carried out
- The T_K time stamp is given
- Pressure P_K and Flux Q_K are calculated
- Conductivity is changed

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- The equivalent of POI's are calculated
- Grid construction
- Initialize the pressure with all-time stamps
- Defining the POI's
- Weight of all edges are calculated
- Minimal road network is identified
- The same is applied to Steiner tree problem

3. **HYBRID GENETIC ALGORITHM BASED MODELS[3]:-**

a) Numerical Functional Extreme Model:-

The authors of the papers were proposed a Numerical Functional Extreme Model (NFEM) with Numerical Computation with Numerical Solutions. The numerical integration finite differences method was proposed by the authors with polygonal lines. First the MEP is converted into NFE Model and then the hybrid genetic algorithm based model is proposed.

b) Hybrid Genetic Algorithm for MEP:-

Part I:- Classical Mathematical Models:-

In this paper, the CMM have been addressed. Due the complication of derivations this models were not used by the authors.

Part II: - Effective Hybrid Genetic Algorithms:-

In this proposed method, the crossover operator was designed first. Then the local search scheme was proposed the up side down operators were also used. Genetic algorithms are developed to give effective search based results for decision problems. These are inspired by evolutionary algorithms which mimics the behavior of evolutionary biology. The genetic algorithms normally have the crossover value, mutation and generation of sample and population.

The proposed method was involving the following steps

Coding and Initializing the population – each chromosome is embedded with real number coding method

Objective Function Extraction – the fitness function is calculated with exposure of the paths

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Selection and population is updating – based on the fitness value the population is updated in regular interval

Generation of Crossover Operators – two types of CO's have been generated such as midpoint crossover and convex combination crossover

Gaussian Mutation – Gaussian mutation is applied to prevent the stagnation of population

Local Search Scheme – under this the quadratic interpolation method is proposed to fine out the local minimum value

Upside down operator – this evolutionary operator is proposed to avoid the sudden jump of the path. The maximum saw tooth degree path is detected and then eliminated using upside down operator

Hybrid genetic algorithm – with the help of CLUD, the effective ME road networks are determined

HGA – NFE – the proposed system was addressed in all dimensions

4. MAXIMUM AND MINIMUM PATH EXPOSURE [4]:-

In this paper the solution models were divided into two types. First one was single sensor optimal solution and the second one was multiple sensor optimal solutions.

a). Single Sensor based Model:

Based on the speed of the objects, the minimal exposure path is identified. In theorem 1, the boundary conditions are used. Followed by theorem 2, the distance between the sensor nodes were calculated in the form of polar coordinates. And in theorem 3, the sensor sensitivity function was measured with minimal exposure value.

b). Multiple Sensor based Model:

In this type the grid based approximation method was proposed by authors. The search messages and forward messages were used, through which the best potential node, worst potential nodes were identified. Based on the potential value the minimum and maximum exposures were calculated. Heuristic search was applied in each iteration. Initially the search messages were sent out through the deployment field. Once the receivers were received the search messages, the potential values were calculated. After that the forward messages were sent by the sender to receiver.

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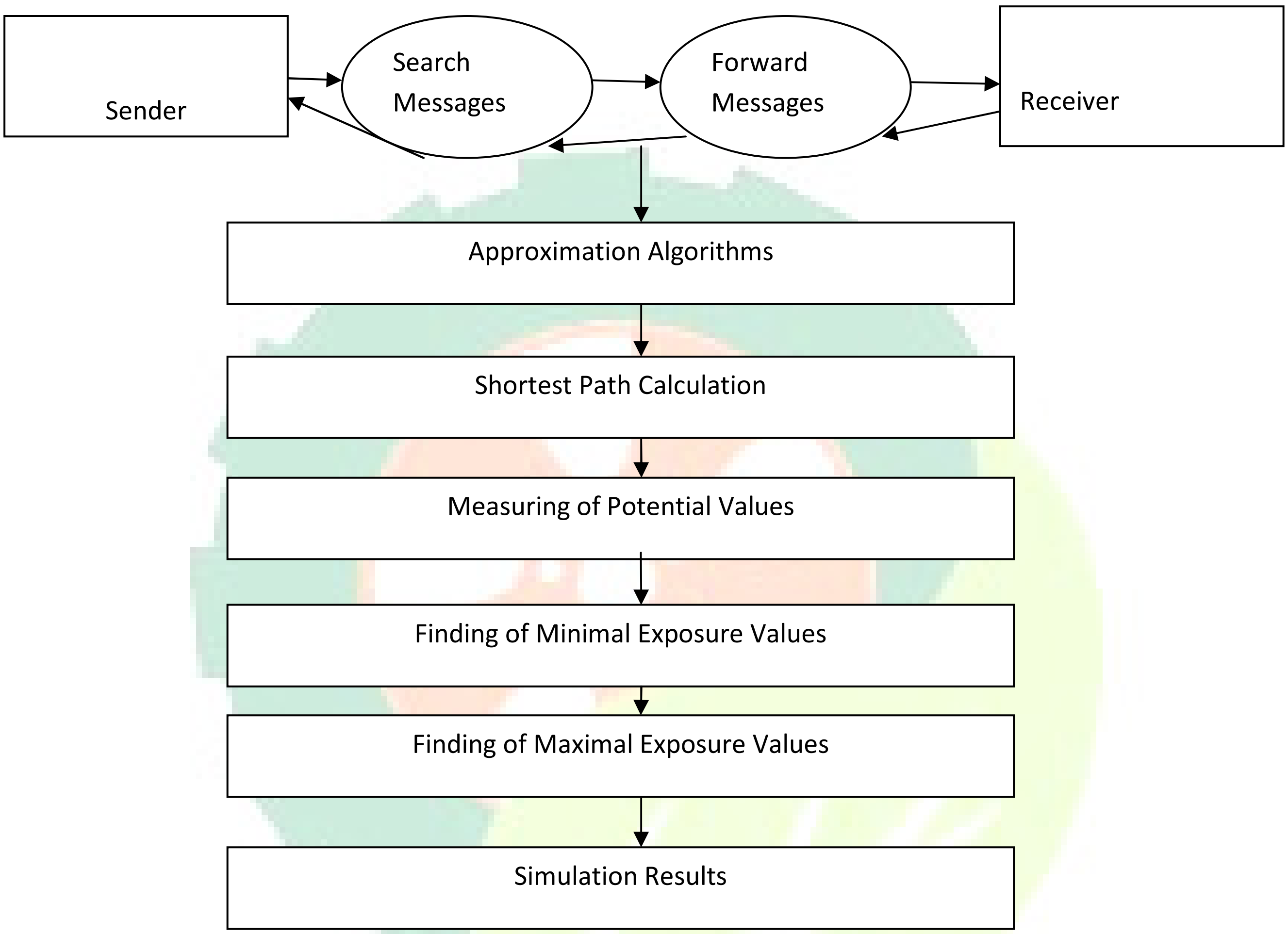

Fig 10:- Flow of MMEP

IV. SIMULATION RESUL COMPARISON:-

a) Biology Based Models :-

In this paper the simulation results were obtained using the platform of VC ++ as per the Fig 11

Fig 11:-

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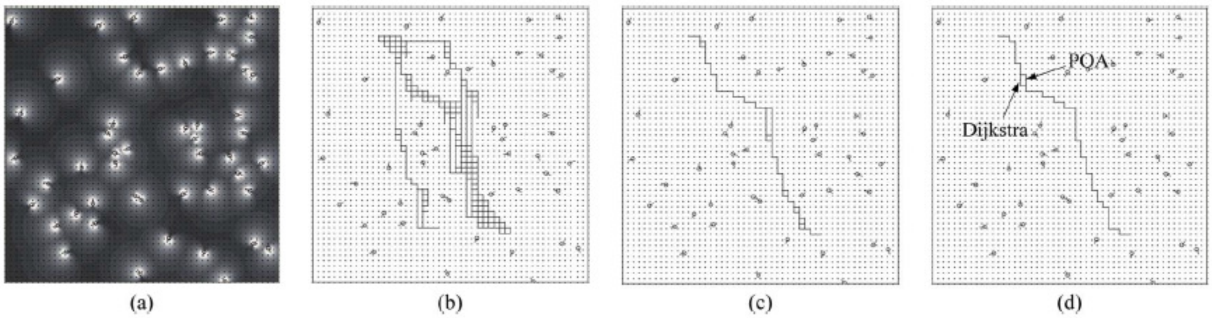


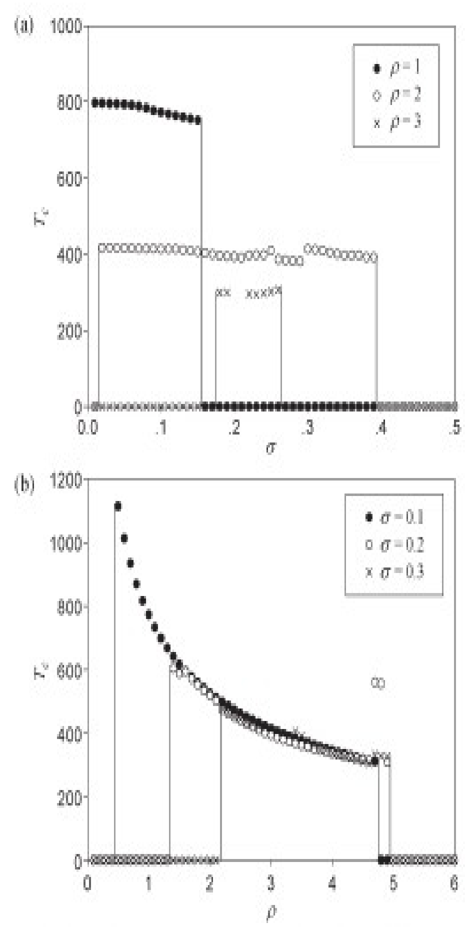
Two examples of the Physarum Optimization for the shortest path problem on a 50 × 50 grid where two PoIs are (120, 450) and (360, 90). (a) Topology of 50 deployed sensors and the corresponding sensing intensity distribution. (b) The intermediate state after 50 iterations. There remain 369 edges. (c) The intermediate state after 200 iterations. There remain 78 edges. (d) Comparison between the final path obtained by 669 iterations and the the shortest path obtained by Dijkstra's algorithm. Their exposures are 9.23 and 9.2, respectively.

Using intensity function the sensing intensities are measured. The above gray scale image is considered as sensing intensity. The image b is about the intermediate states after 50 iterations. And the image c indicates the iteration after 200 times. Image d is expressed as the final path extracted after 600 iterations with Dijikstra algorithm along with POA implementation. The convergence point exposures and effects p and µ are calculated.

The POA results are compared with Steiner tree problem. The obtained exposure values are 24.30 and 29.99 respectively. The middle points are the indicators of monitoring field. And the red circles are indicting the terminals of intruders. The following figure c indicates the solution of Steiner tree problems. The final exposure of the Steiner tree problem is 23.56.

Performance Comparison

The exposure path between E_p and E_d are calculated. The difference between E_p and E_d are considered as precision and the least number of iterations are considered as convergence. The grid size is considered as an important factor in the performance of algorithm. Totally 50 sensors are deployed in the grid representation. Based on the grid size the exposure paths are determined. If the grid size is small then the path is minimal. If the grid



Effects of σ and ρ on convergence. (a) Relationship between σ and T_c with different ρ's. (b) Relationship between ρ and T_c with different σ's.

Fig:- 12 The Effects of Convergence

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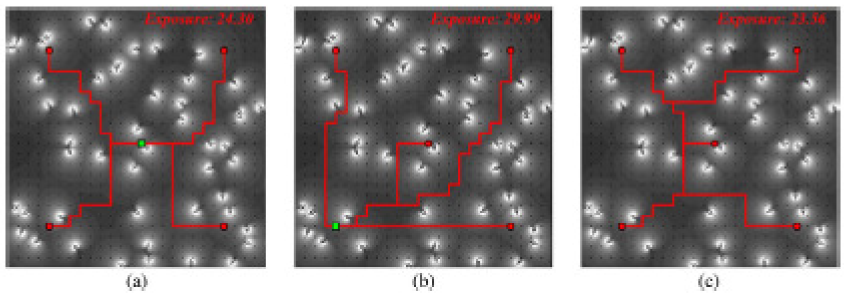
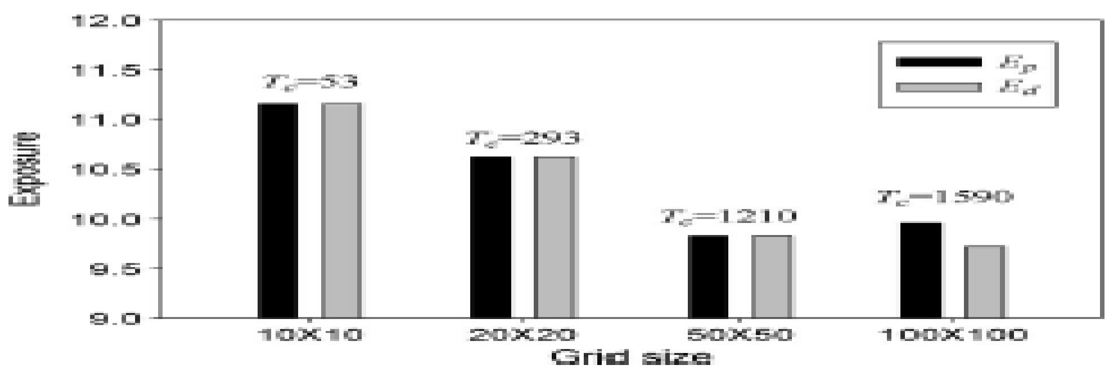
size is big then the exposure is maximal. The final observation is if the grid is increased then the exposure is increased, if it is decreased the exposure is decreased.



The comparison of the exposure value for the Steiner problem with five terminals located at a grid of 25 × 25 lattices. (a) The solution of the rooted Steiner system with the root being at the center of the sensing region. The exposure value of the intrusion road-network is 24.30. (b) The solution of the rooted Steiner system with the root being at the lower left corner of the sensing region, and the exposure value is 29.99. (c) The solution of the Steiner system where the terminals are symmetric. The exposure of the road-network is 23.56.

Fig 13:- The comparison of exposure



Effect of grid size on performance of POA.

b) Physarum Based Models :-

In this paper the VC ++ platform is used to carry the results. 500 x 500 square monitoring field is considered. Direct sensitivity model is considered on sensor deployment field. In this paper the intensity function is used to derive the sensing intensity. 25 x 25 lattices are generated first in the observation field. Initially the minimal exposure path is observed with single POI's.

Then the initial pressure is measured with the two POI's. Finally different road networks are found with multiple POI's. Based on the sensor intensity function the sensing region is

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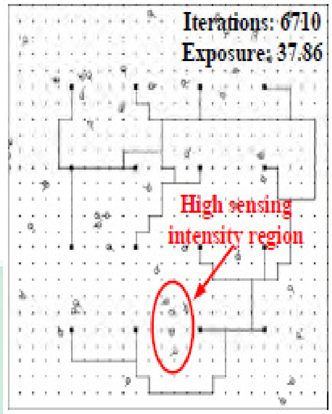
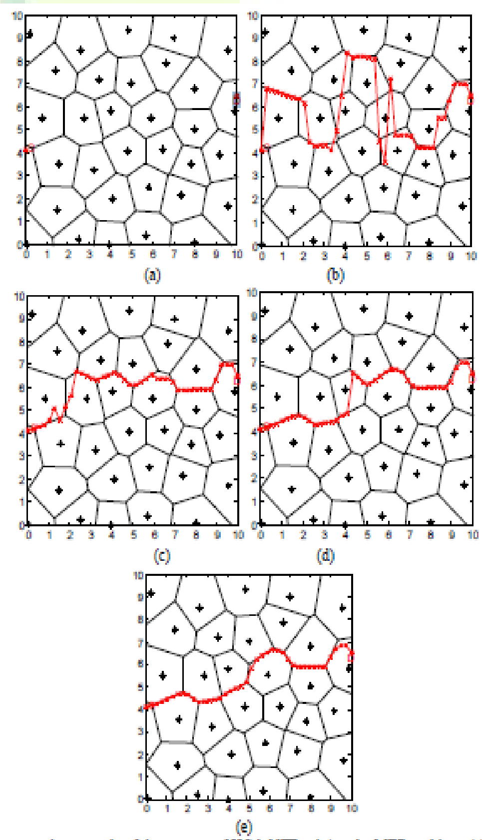


identified. At the end the high intensive road networks are observed.

The biological based physarum model is proposed to identify the minimal exposure problem with single POI's to multiple POI's. Then the concept is applied to Steiner tree problem.

Fig 14:- Sensor Intensity

Fig 15:- Comparison of Models



An example of the process of HGA-NFE solving the MEP problem. (a) Locations of sensor nodes. (b)-(e) MEPs found in different generations of the evolutionary process

c) Hybrid Genetic Algorithm Based Models:-

In this paper the authors are used Mat lab 7.6.0 to carry the simulation results. The results of the grid based method and voronoi diagram based method are compared. This simulation results are classified randomly deployment cases.

Randomly Deployment Case:

The authors of the paper are constructed 10 x 10 monitoring field for using 30 sensors on the deployment filed. Two dimensional distributed random variables are used to generate the positions of the sensors. In this deployed topology, source node and destination node are marked respectively along with Voronoi edges. Crossover, mutation and population sizes are assigned with upside down operator. The MEP points are observed from source S to destination D. Finally the fitness values are identified.

Measurement Table:

The performance table is constructed by applying the exposure values and time duration.

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TABLE I
EXPOSURE VALUE AND EXECUTION TIME COMPARISON OF HGA-NFE WITH THE GRID-BASED METHOD AND VORONOI-DIAGRAM-BASED METHOD

n	HGA-NFE method		Grid-based method		Voronoi-diagram-based method	
	exposure	*time*	*exposure*	*time*	*exposure*	*time*
40	**42.5916**	36.3427	57.0373	42.7584		
80	**43.0125**	83.7606	55.0518	178.2976	47.4402	4.5976 4
100	**43.3752**	132.909	54.6562	274.2848		

This above table depicts the better precision and good time performance of performance

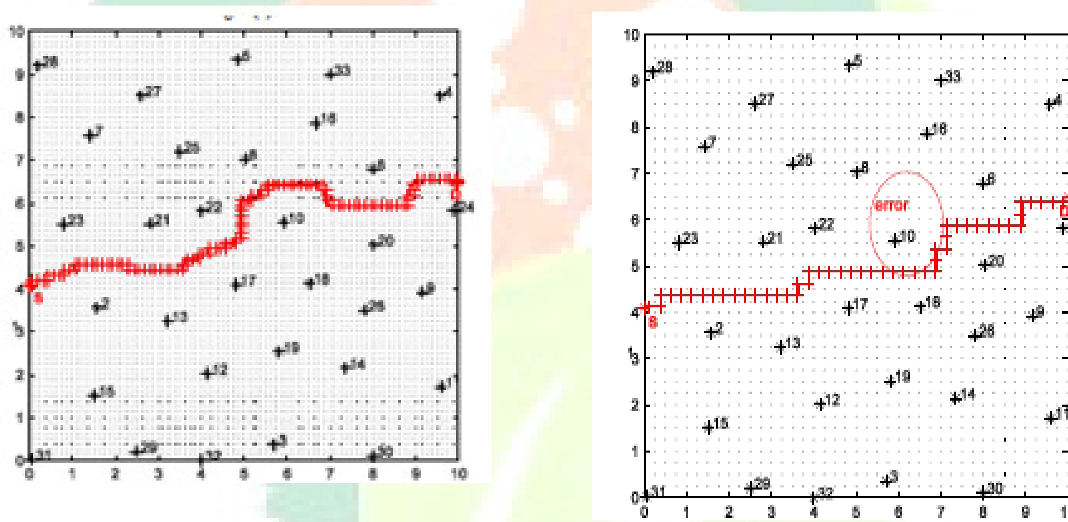
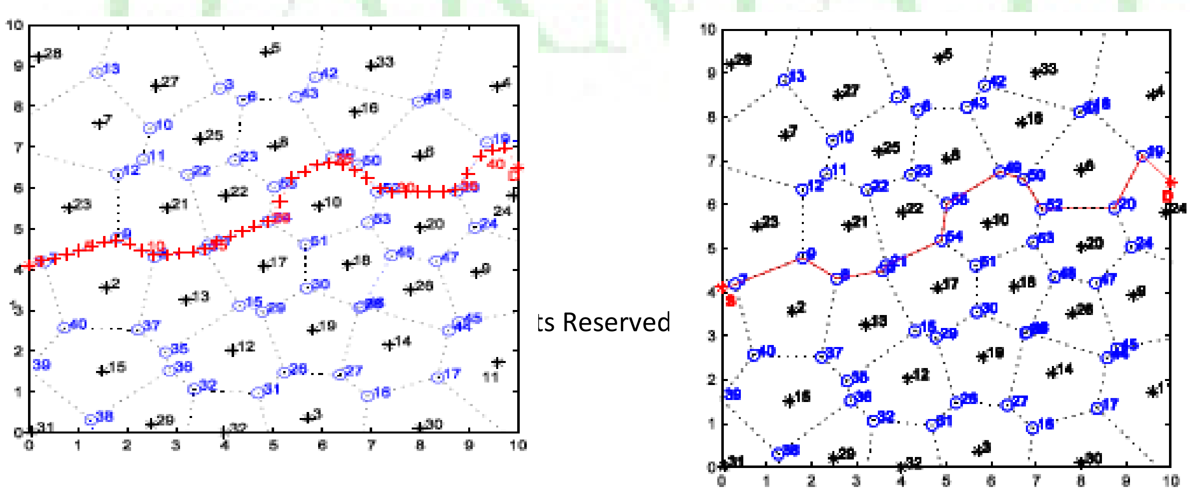


Fig 16:- Simulation Results

The above figure gives the error scenario and correct scenario. The comparative analysis is also done.



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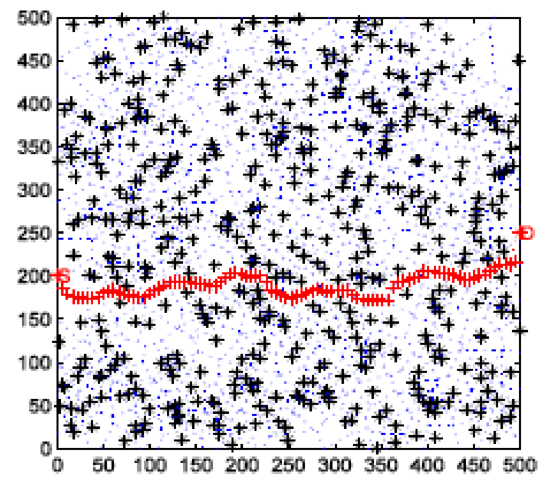
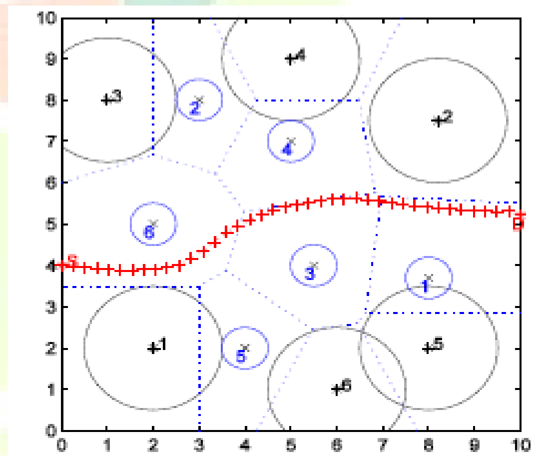
Comparison Analysis:-

The grid based method, Voronoi method and proposed HGA-NFE method is compared with the respective simulation results. The obtained exposure values are compared. Based on the fitness value the performances are analyzed. In heterogeneous case all sensor intensity functions are measured. Here 500 sensor are deployed randomly. Here the different values are sensing parameters are used.

In this following diagram the small circles are denoted first type of node and big are considered as second type of nodes. In the first types the sensing abilities are weaker. But in the second type the sensing abilities are stronger.





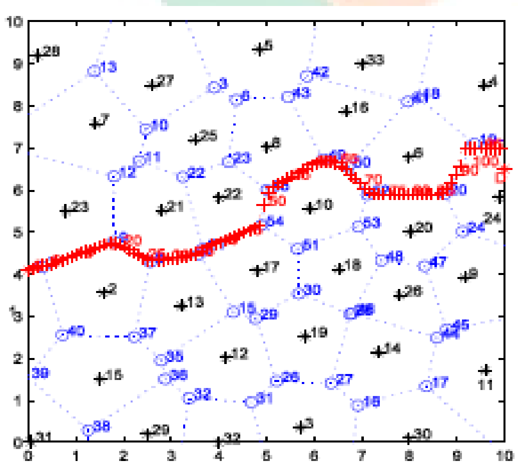


Fig 17:- Comparison

d) Maximum And Minimum Path Exposure Models:-

In this paper the approximation algorithms are proposed to determine minimal exposure ratio with the 21 different cases. The no of nodes are assigned in x axis and exposure ratio is assigned in y axis. The possible combinations are measured as 5, 8, 10, 13, 15 & 18.

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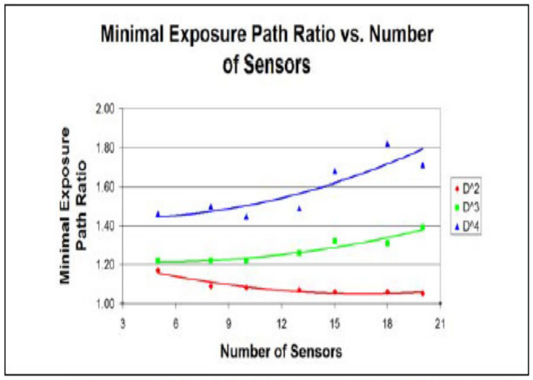
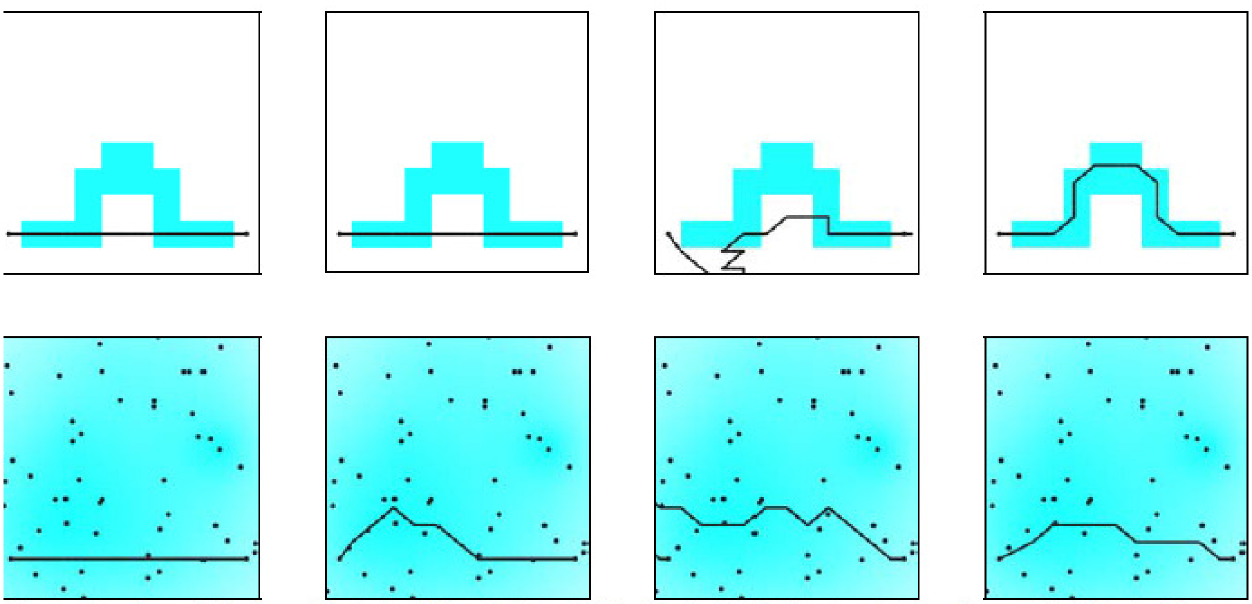


Experimental results for the minimal exposure path algorithm.

The maximal exposure values are observed based the maximum distances of the object. The delay of object is calculated. The maximal velocity is extracted. The authors of the papers are also stated that the maximal exposure problem is NP hardproblem



Demonstration of the four heuristics (from left to right: shortest path, best point, random path, adjusted best point)

- **1. Random Path Heuristic Search:-**

  The nodes are selected randomly. So the resulting path is so larger and longer.

- **2. Shortest Path Heuristic Search:-**

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This approach is considered as an inferior because of the inefficient results on minimal exposure path.

4. **Best Point Heuristic Search:-**

The best points are noted in each iteration. The points are giving the good exposure path

. **4. Adjusted Best Point Heuristic Search:-**

The best point search does not provide the quality of solution. Hence this adjusted point method is introduced. Here the three adjustments are assumed, such as moving a node, adding a node and deleting a node.

CONCLUSION:-

The main applications of sensor networks are object tracking. In a deployment field, the multiple objects tracking and finding the intruder is very tedious task. Exposure path finding through the sensor deployment field is a major research challenge in WSN. This exposure is even classified into minimal and maximal for certain times. So to find out the efficient exposure path gives the sensor node object travelling path identification. In this paper, the research study of various proposed methods have been studied for minimal exposure and maximal exposures. The different parameters are used by the authors of these papers. In a paper the initial pressure values are used and based on that the proposed algorithms are applied. The biological inspired models are produced the better results. In some papers physarum based biological models are proposed with particle optimization algorithms. Based on the maze solving behavior of physarum the proposed algorithms are developed. In some other paper, the voronoi based model, grid based model and hybrid models are proposed. Based on the sensor intensity function the sensing abilities are presented. The simulation results are carried out using VC ++ and Mat Lab environments. The gird based lattices are constructed to view the simulation results. The tables are formulated with the comparison of performance metrics and values. In future the particle swarm intelligence optimization techniques are used to carry the efficient results. Such as ant colony, bee's colony, and fire fly algorithms will be used.

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