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Indoor RFID Network Planning by Different Intelligent Optimization Strategies

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Abstract: **Radio Frequency Identification (RFID) is a technique used for identification or tracking of objects. The fast development of RFID technology generates the most challenging RFID network planning (RNP) problem to cover all the tags in area by the readers with minimum cost. The optimization of RFID network becomes a necessary technique to minimize overall cost of RFID network. This paper presents different intelligent optimization strategies to distribute the minimum number of readers to cover all tags in a given area and define locations of readers in the RFID network. Six well known techniques have been studied; namely Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Bee Colony Optimization (BCO), Flower Pollination Algorithm (FPA), Spider Monkey Optimization (SMO) and Tabu Search Algorithm (TSA). The algorithms are applied over three typical test areas, (10m×10m), (16m×12m) and (18m×14m) respectively. All methods for planning were implemented by building a Graphical User Interface (GUI) software tool using MATLAB. The GUI is used to input the dimensions of the required area and calculate the initial number of readers and tags which are distributed randomly in the area. The obtained results confirm that all the tested algorithms are promising for optimum planning of indoor RFID networks with different percentages in cost reduction reaching up to 55% in some cases.**

Keywords: RFID, network Planning, Intelligent Optimization Strategies, PSO, ACO, BCO, SMO, FPA, TSA

I. Introduction

Radio Frequency Identification (RFID) is a wireless technology for identification of people, objects and animals. The RFID technique assisted to speed up different processes in several industries, without the requirement of line of sight as compared to the conventional barcode technology [1]. A typical RFID network consists of readers, tags, a computing hardware, application software and a middleware. The tag or transponder is a basic component of the RFID system, which is a microprocessor chip containing the electronically memorized data. In general, when a tag is in the read-range of an RFID reader, it is activated to transmit the data stored on its memory chip to the reader [2]. The applications of RFID techniques are divided into two main categories: (i) short range applications where the reader and tag must be in close nearness, and (ii) long range applications in which the distance may be greater [3]. The fast development of RFID technology generates a challenging RFID network planning (RNP) problem, which lead to the utilization of optimization strategies so as to cover all the tags placed in a specific indoor area by readers [4]. Swarm Intelligence Algorithms are a search technique used in the problems of search and optimization to find the optimal solutions. The basic idea of these algorithms is based on the biological behavior of natural objects. Swarm Intelligence (SI) is the name of a technique or system that consists of a set of particles, workers, agents that works in collaboration with each other to find the optimal solution for the problem. Several examples of SI groups are ant colony, bird flocks, particle swarm, bee colony, cockroaches, fishes, etc. [5].

In this research paper a comparative study will be conducted among six different algorithms. The study will include the following concepts:

- Attempt to use swarm intelligence (PSO, ACO, BCO, SMO, FPA, and Tabu) in an RFID network planning.
- Examine the effect of two important parameters used to evaluate the fitness of the solution, which are (coverage and cost).
- Build a GUI for network planning and optimization, to enable a graphical input for the required area, a number of readers, the algorithm parameters, and the number of tags and their locations.
- Compare the coverage and cost reduction percentages for all algorithms.

Section 2 describes a review of some previous work done on indoor RFID network planning and intelligent optimization. Section 3 explains the necessary information needed in the RFID network planning such as the area information, and the objective function parameters. Section 4 presents the six intelligent optimization techniques in our study and their flowcharts. Section 5 discusses the areas used in the simulation tests and the results. Finally, section 6 includes the discussion and conclusion.

II. Related Work

M. Z. Zakaria and M. Y. Jamaluddin in 2015 [6] proposed a novel technique to obtain the shortest path for an RFID mobile reader and with guarantee 100% coverage in the given area, by using Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) techniques. The results showed that the ACO algorithm is better than PSO algorithm for solving discrete optimization problems like path optimization. K. Hasnan *et al*. in 2015 [7] suggested a novel model of Multi-Colony Global Particle Swarm Optimization (MC-GPSO) algorithm to distribute the minimum number of readers to cover all tags with minimum interference in large scale. The implementation of this algorithm succeeded in reaching the optimum reduction in the overall cost of the RFID planning network. N. Bacanin, M. Tuba and I. Strumberger in 2015 [8] presented the application of Artificial Bee Colony (ABC) algorithm for solving the RFID network planning for determining the initial number and locations of RFID readers. The simulation results showed that the proposed algorithm works well for finding the best solutions. K. Singh and A. Aggarwal in 2016 [9] suggested several techniques of optimization for RFID in the Internet of Things. The paper studied and compared in some details the implementation of the following four algorithms: Differential Evolution, Particle Swarm Optimization, Genetic Algorithm and Ant Colony Optimization.

III. Methodology of RFID Network Planning

The RFID network consists of a number of tags and readers. It is important to determine the best locations of readers depending on the coverage (the tag locations). The necessary information needed to be known such as the area information, the fitness function parameters, and other concepts concerned about the methods of planning.

A. The Area Information

The area information can be divided into two categories: the readers information and the tags information.

1) The Readers Information

This information is concerned with the readers, which consists of the reader - tag read range, and the number of initial readers needed to cover the overall area. The number of initial readers will be denoted as N_{max}. If each reader range is defined by a radius of circle equal to *range* units, then to guarantee a complete coverage for adjacent readers, the distance between the centres of these adjacent readers is then defined by *d* units where ($d = (\sqrt{2}\ range)$) [10].

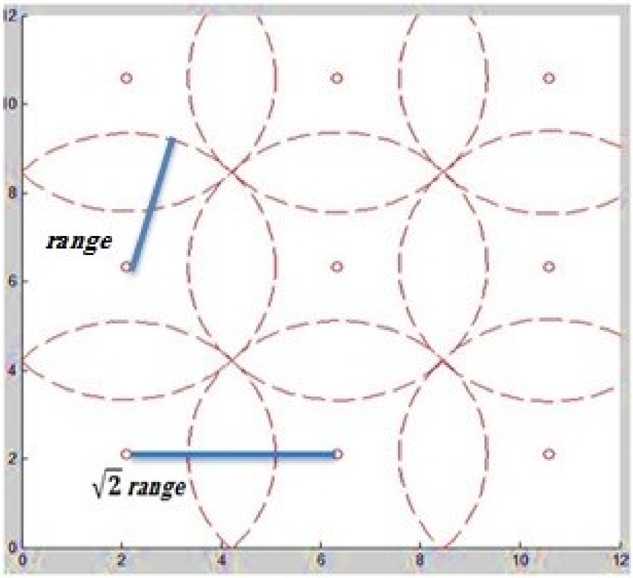


Figure 1. The number of initial readers N_{max} and the distance between the readers

2) The Tags Information

The number and locations of tagged items must be carefully known. The number and locations of tags will lead to get the coverage vector matrix and overlapped regions matrix shown in Figure 2, which are the most important matrices needed to be known to apply the optimization process.

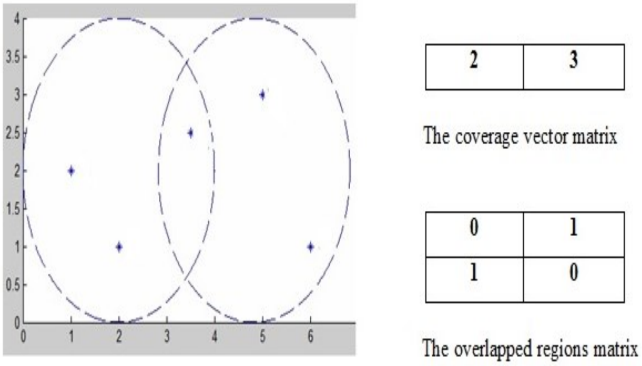


Figure 2. The coverage vector and overlapped regions matrices

B. The Fitness Function Parameters

The fitness function is used to evaluate a fitness of each particle and has the following two considerations: coverage and cost.

1) The Coverage Parameter

This parameter of the fitness function is concerned about the number of tags covered by the readers and is taken as a ratio of the number of these tags to the total number of tags in the area.

$$Coverage = \frac{C_{Tag}}{T_{Tag}} \tag{1}$$

Where C_{Tag} is the number of tags covered by the available readers and T_{Tag} is the number of total tags in the area.

2) *The Cost Parameter*

This cost parameter of the objective function is the number of readers used in the solution and is calculated as follows:

$$Cost = \frac{N_{max} - N_{av}}{N_{max}} \quad (2)$$

Where N_{max} is the number of initial readers that covers the entire area and N_{av} is the number of readers available in the current particle.

IV. Optimization Techniques

Optimization is a method for making a system, design or decision as perfectly, functional or effective as possible. In other words, finding an alternative solution with the most cost effective or highest achievable performance under the given limitations, by increasing the requisite factors and reducing undesired ones. The optimization refers to the both tasks of maximization and minimization, since the maximization of any task is mathematically equivalent to the minimization of its additive inverse [9].

A. Particle Swarm Optimization

The approach of PSO technique is a population based stochastic that was developed to solve the optimization problems or a nonlinear continuous and discrete complex search [11]. The PSO is an intelligent technique originated from nature and evolutionary computations, was developed by Kennedy and Eberhart [5]. The flow chart of PSO is show in Figure 3.

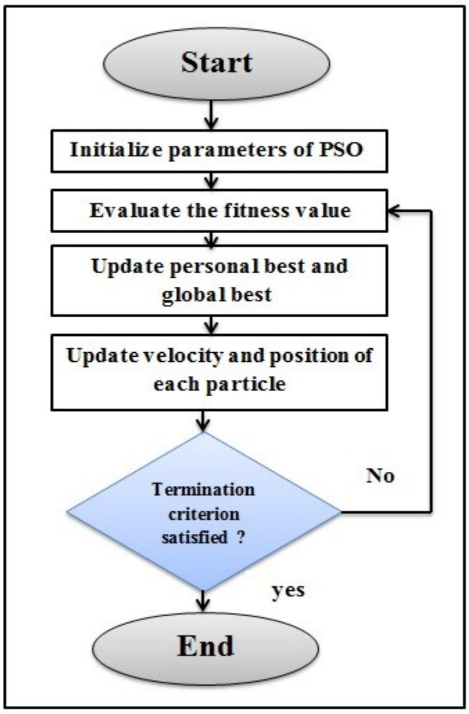


Figure 3. Flowchart of PSO

B. Ant Colony Optimization

The Ant Colony Optimization is a one of swarm intelligence technique that is used for solving optimization problems. ACO was the first algorithm to search for optimal path, suggested by Marco Dorigo in 1991 in his PhD thesis, based on the behavior of ants for finding the shortest path in search of food sources [12].The flow chart of the ACO is show in Figure 4.

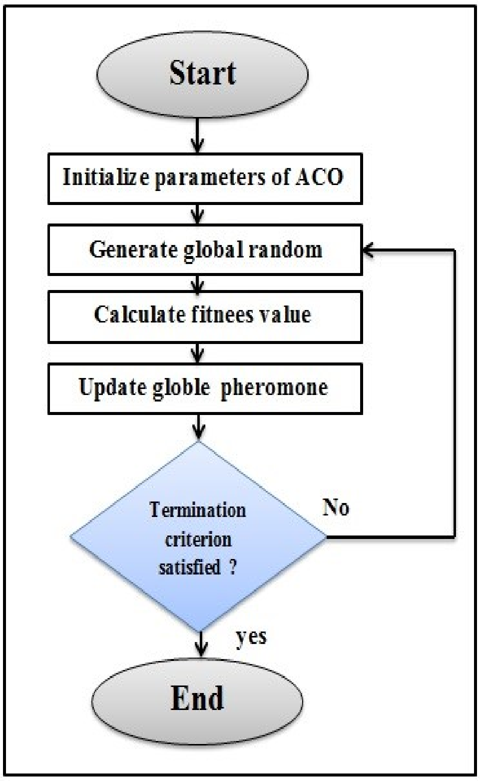


Figure 4. Flowchart of ACO

C. Bee Colony Optimization

Bee colony optimization (BCO) algorithm is one of swarm-based optimization algorithms. BCO algorithm was proposed by Karaboga in 2005 inspired by the bees behavior in nature and has been shown to be competitive with other population-based algorithms for the global numerical optimization problem with the benefit of employing fewer control parameters [8]. Figure 5 shows the flow chart as depicted by the algorithm of BCO.

D.Spider Monkey Optimization

Spider Monkey Optimization (SMO) is an algorithm inspired by the intelligent search behavior of fission–fusion social structure based animals proposed by J. C. Bansal *et al.* in 2013 [13]. SMO algorithm is based on the foraging behavior of spider monkeys. These monkeys fall in the category of fission-fusion social structure (FFSS) based animals [14]. The flowchart of the SMO algorithm is shown in Figure 6.

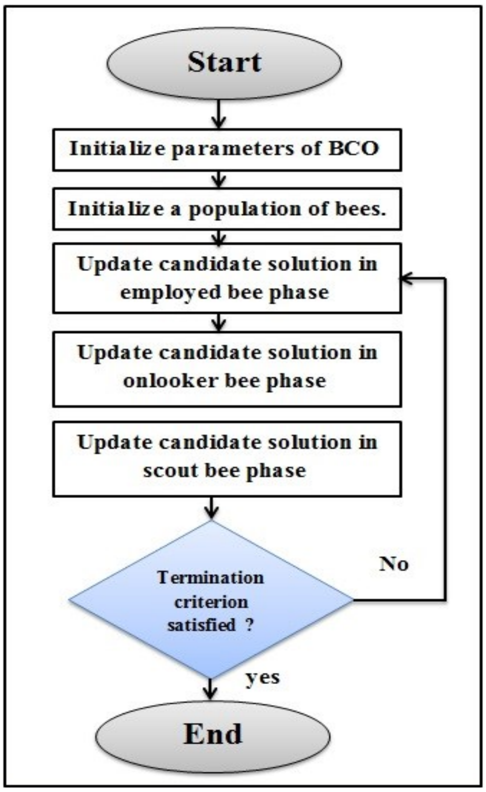


Figure 5. Flowchart of BCO

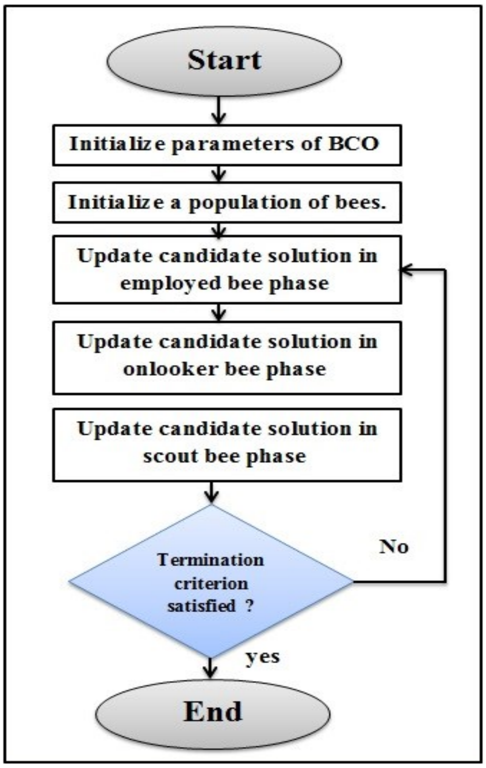


Figure 6. Flowchart of SMO

E. Flower Pollination Algorithm

Flower Pollination Algorithm (FPA) is a population-based intelligent optimization algorithm proposed by Yang in 2012. (FPA) is a novel bio-inspired optimization algorithm that simulates the real life processes of the flower pollination [15].The flow chart of this algorithm is shown in Figure 7.

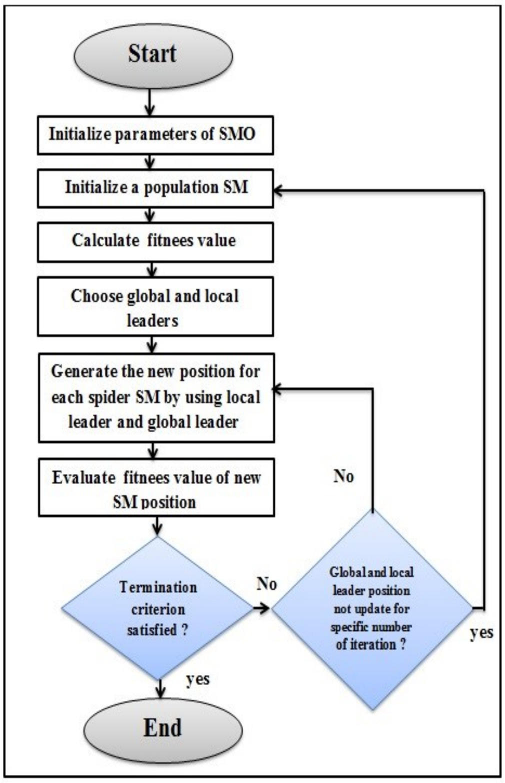


Figure 7. Flowchart of FPA

F. Tabu Search Algorithm

Tabu Search Algorithm (TSA) is an intelligent search method proposed by Fred W.Glover. It employed local search methods for mathematical optimization [16]. The flow chart of this algorithm is as depicted in Figure 8.

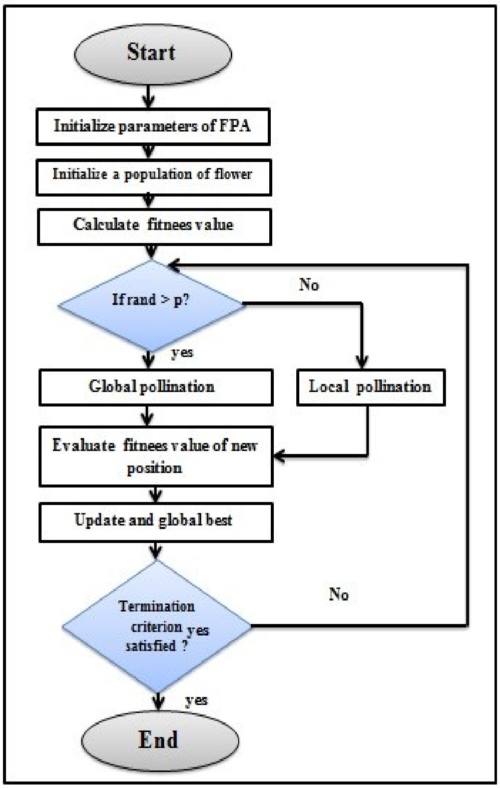


Figure 8. Flowchart of TSA

V. Simulation Results

In this work the following three scenarios are considered for the working areas: (i) (10m x 10 m), (ii) (16m x 12m) and (iii) (18m x 14m) respectively. By using UHF readers with read range of (3 m) and capability to read multiple RFID tags at once. In Area 1 the initial number of RFID readers are (10) readers and the number of tags is (180). In Area 2 the initial number of RFID readers is (12) readers and a number of tags is equal to (240) tags. Finally, in Area 3 the initial number of RFID readers is (20) readers and the number of tags is equal to (400) tags. The tags are randomly distributed in the working space. Plotting of the selected areas, the number of tags (shown as a blue star '*') and the initial number of RFID readers (shown as a red circles 'O') in order to cover all the tags are shown for the three scenarios in Figure 9, Figure 10 and Figure 11 respectively.

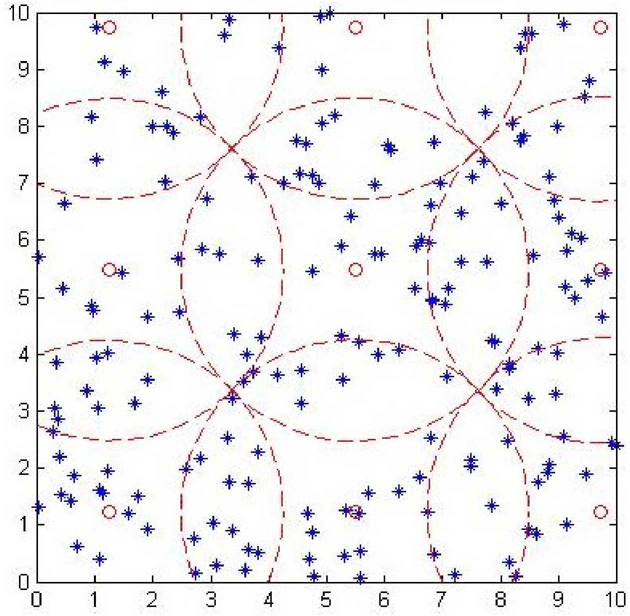


Figure 9. Area 1 (10x10) m

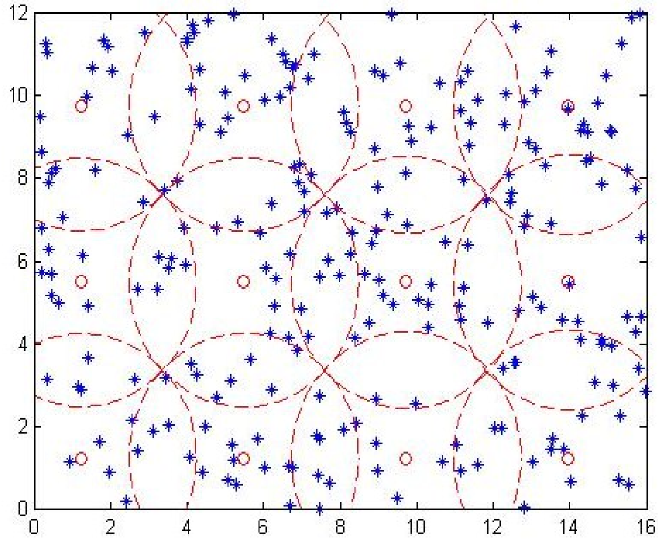


Figure 10. Area 2 (16x12) m

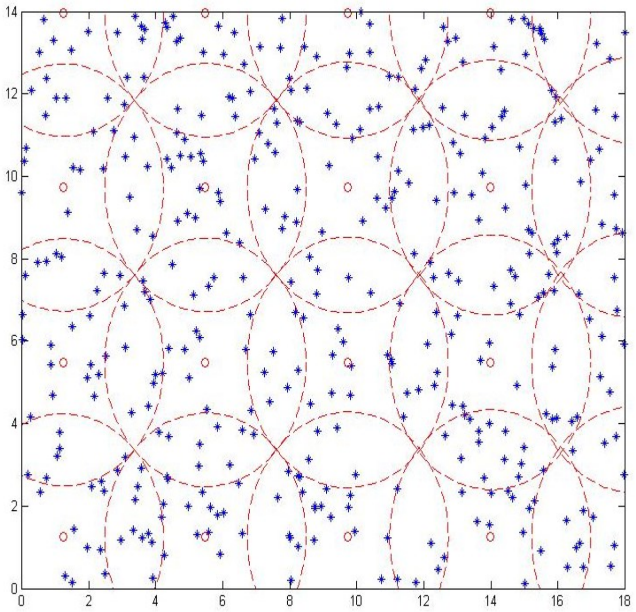


Figure 11. Area 3 (18x14) m

All the six algorithms under studied were implemented in the three areas and their optimization results are shown in Table 1, Table 2 and Table 3 respectively. In this experiment, we assume a best coverage between (95-100%) and after the implementation of each algorithm the final numbers of readers are displayed in these tables with different times and iteration numbers.

Table 1. Comparison results of algorithms for Area 1

Area 1 (10x10) m

Algorithm	Number of Iterations	Number of Readers	% Cost Reduction
PSO	45	5	44
ACO	25	4	55
BCO	8	5	44
SMO	60	4	55
FPA	24	4	55
TSA	15	4	55

Table 2. Comparison results of algorithms for Area 2

Area 2 (16x12) m			
Algorithm	**Iteration Numbers**	**Reader Numbers**	**% Cost Reduction**
PSO	**90**	**9**	**25**
ACO	**83**	**8**	**33**
BCO	**12**	**9**	**25**
SMO	**250**	**8**	**33**
FPA	**20**	**8**	**33**
TSA	**60**	**8**	**33**

Table 3. Comparison results of algorithms for Area 3

Area 3 (18x14) m			
Algorithm	**Iteration Numbers**	**Reader Numbers**	**% Cost Reduction**
PSO	**110**	**13**	**35**
ACO	**52**	**12**	**40**
BCO	**16**	**13**	**35**
SMO	**230**	**12**	**40**
FPA	**32**	**12**	**40**
TSA	**63**	**12**	**40**

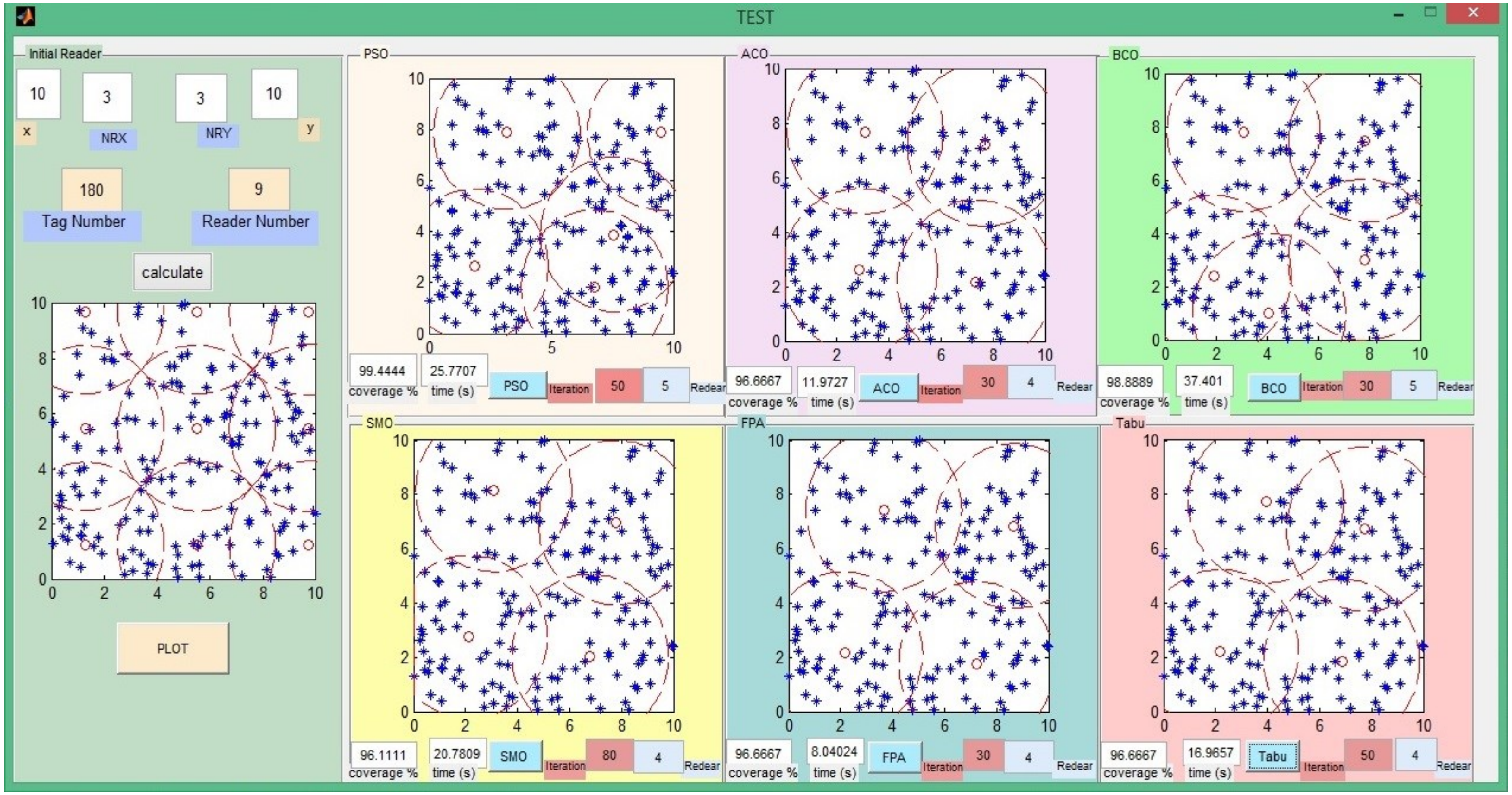
The numbers and locations of readers of each of the six implemented algorithms for Area 1, Area 2 and Areas 3 are shown in Figure 12 Figure 13 and Figure 14 respectively.

VI. Discussion and Conclusion

In this work, we used typical open indoor areas to study six well known intelligent optimization algorithms for planning indoor RFID networks to optimize coverage with a minimum number of readers and hence the best possible reduction in the cost.. All algorithms optimize the planning of RFID networks in different feasibility and effectiveness. The results show that all six algorithms have competitive potential for solving discrete optimization problems.

The obtained results for Area 1 showed that the algorithms of PSO and BCO reduce the cost by 44%, while algorithms ACO, SMO, FPA and TSA reduce the cost by 55%. In Area 2 the algorithms of PSO and BCO reduce the cost by 25%, while the cost reduction for algorithms ACO, SMO, FPA and TSA reaches 33%. In Area 3 the algorithms of PSO and BCO succeed in reaching a cost reduction of 35%, while in the algorithms of ACO, SMO, FPA and TSA the cost reduction is 40%. As a result the algorithms of ACO, SMO, FPA, and TSA are more effective than PSO and BCO for cost reduction of RFID networks.

As a final conclusion, all studied methods achieve promising results for planning RFID networks with different percentage of cost reduction. The encouraging outcomes of this paper will certainly lead to a future studies in RFID network optimization for different sizes and geometry of indoor working areas.



Initial Reader
x 10
NRX 3
NRY 3
y 10
Tag Number 180
Reader Number 9

PSO
coverage % 99.4444
time (s) 25.7707
Iteration 50
Redear 5

ACO
coverage % 96.6667
time (s) 11.9727
Iteration 30
Redear 4

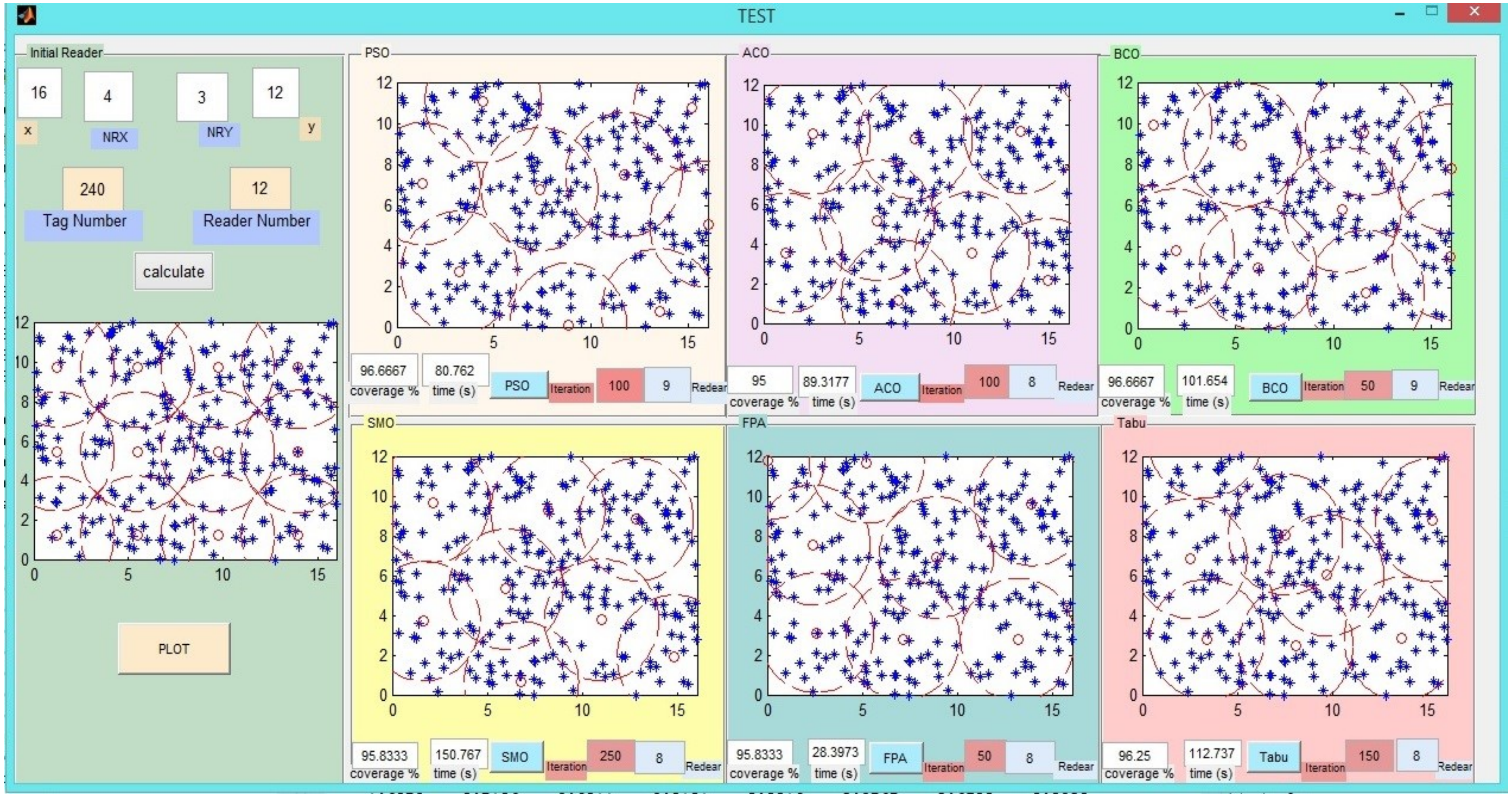
BCO
coverage % 98.8889
time (s) 37.401
Iteration 30
Redear 5

SMO
coverage % 96.1111
time (s) 20.7809
Iteration 80
Redear 4

FPA
coverage % 96.6667
time (s) 8.04024
Iteration 30
Redear 4

Tabu
coverage % 96.6667
time (s) 16.9657
Iteration 50
Redear 4

Figure 12. Numbers and locations of readers for Area 1



Initial Reader
x 16
NRX 4
NRY 3
y 12
Tag Number 240
Reader Number 12

PSO: coverage % 96.6667, time (s) 80.762, Iteration 100, Redear 9

ACO: coverage % 95, time (s) 89.3177, Iteration 100, Redear 8

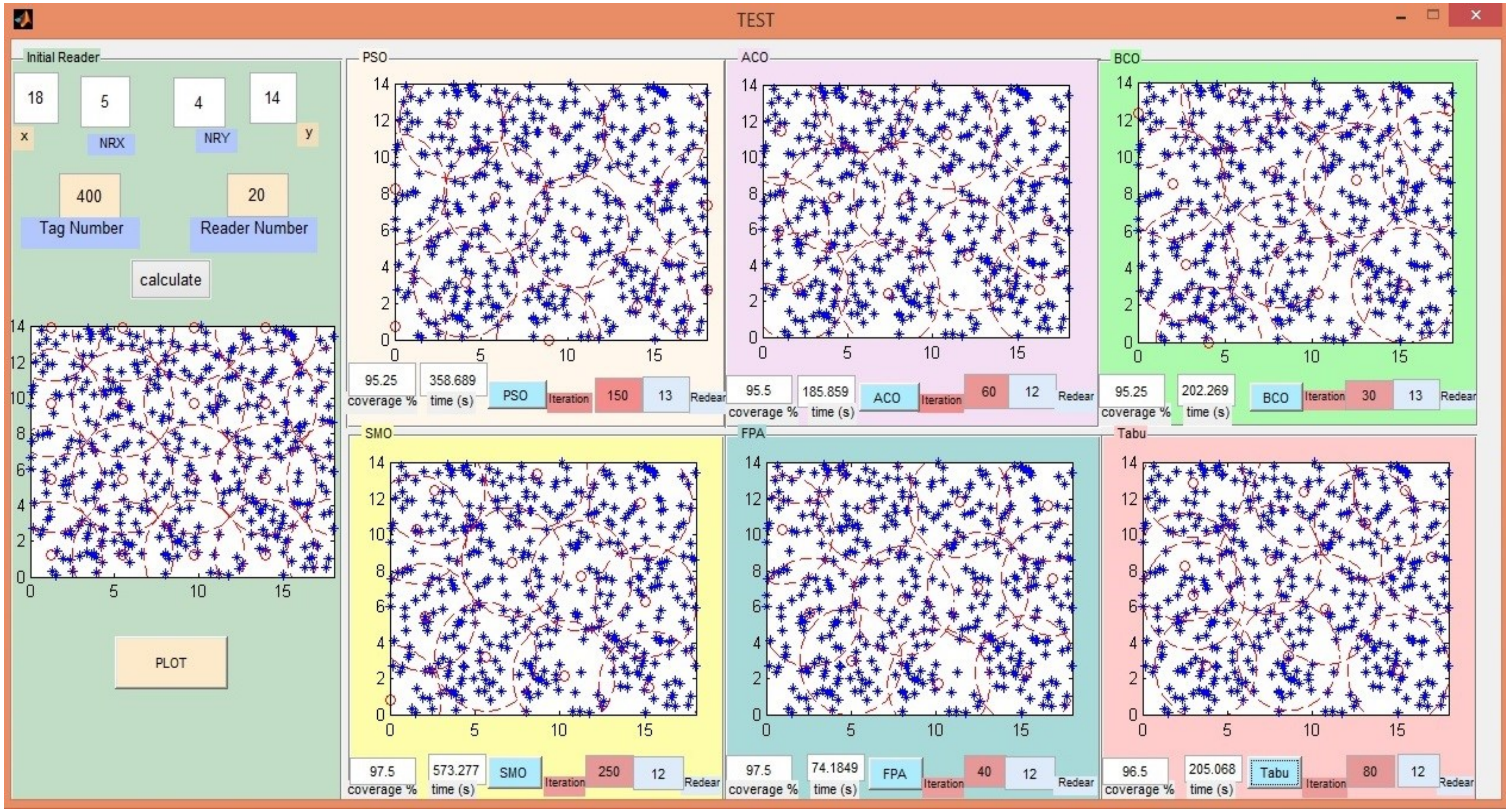
BCO: coverage % 96.6667, time (s) 101.654, Iteration 50, Redear 9

SMO: coverage % 95.8333, time (s) 150.767, Iteration 250, Redear 8

FPA: coverage % 95.8333, time (s) 28.3973, Iteration 50, Redear 8

Tabu: coverage % 96.25, time (s) 112.737, Iteration 150, Redear 8

Figure 13. Numbers and locations of readers for Area 2



Initial Reader
x: 18
NRX: 5
NRY: 4
y: 14
Tag Number: 400
Reader Number: 20

PSO: coverage % 95.25; time (s) 358.689; Iteration 150; Redear 13

ACO: coverage % 95.5; time (s) 185.859; Iteration 60; Redear 12

BCO: coverage % 95.25; time (s) 202.269; Iteration 30; Redear 13

SMO: coverage % 97.5; time (s) 573.277; Iteration 250; Redear 12

FPA: coverage % 97.5; time (s) 74.1849; Iteration 40; Redear 12

Tabu: coverage % 96.5; time (s) 205.068; Iteration 80; Redear 12

Figure 14. Numbers and locations of readers for Area 3

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His current research interests include intelligent optimization techniques, computer aided design of large electrical circuits, analog and digital signal processing, solar tracking systems and design of smart home energy managements. Professor Al-Naima is a Life Fellow Member of the IETE, India since 1999, and a Senior member of IEEE.

Shahad A. Yousif received her BSc. degree in Computer Engineering from the College of Engineering, Al-Nahrian University, Baghdad- Iraq in June 2012. She is working toward completing her MSc degree in Computer Engineering in the same university