



A Sustainable Scheme for Minimizing Energy in Visual Sensor Network using Disjoint Set Cover Approach

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KEY WORDS

Deployment, Energy Consumption, Field of View, Target Oriented, Targets Coverage, Wireless Visual Sensor Networks.

ABSTRACT

Directional sensors in wireless visual sensor networks attract growing attention as a promising tool for monitoring the real world; directional sensors consume energy for two main tasks: sensing and communication. Since a VSN contains a number of configurable visual sensors with changeable spherical sectors of restricted angle known as a field of view that is intended to monitor a number of targets located in a random manner over a given area. Therefore maximizing the network lifetime through minimizing power consumption while covering the targets remains a challenge. In this paper, the problem of obtaining a disjoint set cover includes a minimum number of camera sensors is solved. The problem is known to be NP-complete. The sustainable design is improving an existing Iterative Target Oriented Algorithm (ITOA) to cover moving targets move randomly over a given area of deployment starting from entry points reaching to exit ones in a realistic simulation. To evaluate the performance of the modified algorithm, a comparison is provided with three existing algorithms (Iterative centralized Greedy Algorithm (ICGA), Iterative Centralized Forced-directed Algorithm ICFA, and Iterative Target Oriented Algorithm ITOA). Simulation results revealed that the sustainable scheme can find a disjoint set with a minimum number of sensors covers the maximum number of moving targets in an energy-efficient way and extended network lifetime.

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1. INTRODUCTION

A Visual Sensor Network (VSN) is commonly comprised of a large number of sensor nodes with limited energy and has been widely applied in many areas such as environment monitoring, traffic surveillance, physical security and so forth. In many surveillance scenarios, such as battlefield, there are some known critical locations where the events of concern are expected to occur. A common goal in such applications is to use sensor nodes to monitor these critical locations with sufficient quality of surveillance with lifetime constraints. However, due to the limited energy of sensor node, it may not be possible to meet both coverage and lifetime requirements; Therefore, how to minimize the power consumption of nodes reasonably to maximize the coverage targets and ensure the specified network lifetime is of great research significance [1].

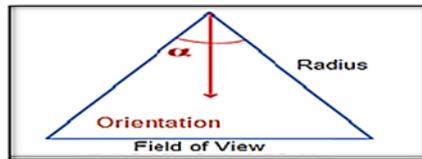
Energy consumption is considered as one of the critical issues that influence VSNs design. Many researchers have been addressing essential issues of VSNs to extend network lifetime such as the optimum sensors placement, energy-efficient management to assure secured connections of the network. Within this concern, it is of primary importance to cover the entire targets with a limited number of sensors. Cardei et al. [2] suggested an omnidirectional sensor technique for extending the lifetime of the sensor network by arranging the sensors into a maximum amount of set covers that are enabled consecutively. Their work considers only Omni-directional sensors that always have an Omni-angle of sensing range. Ai and Abouzeid [3] studied the problem of directional sensor coverage with tunable orientations under the random deployment approach and described the problem by a formulation of an Integer Linear Programming (ILP) to find an appropriate solution to the problem. As a result, because of its high computational complexity, it is not appropriate for relatively large sensor networks. Ai and Abouzeid [3] also created a Centralized Greedy Algorithm (CGA) and its relaxed version Distributed Greedy Algorithm (DGA), which was practically implementable. They have not addressed the disjoint set cover issue. Cai et al. [4] defined subsets of sensors to cover a target, with individual sensors sharing in one or more cover sets. Only one subset is activated at any time, saving energy by deactivating the remaining sets. They suggested non-disjoint cover sets to extend the network lifetime. Munishwar and Abu-Ghazaleh [5] stated a heuristic, which is called Target -Oriented for maximizing the coverage where they first cover the critical targets and greedily pick a sensor that covers most of the targets along with the critical one. They also presented a Centralized Forced Algorithm (CFA) and its modified model Distributed Forced Algorithm (DFA) where they shed light on assuring maximum coverage, their selection schemes are based on the Sensor-Oriented approach. Ahn and Park [6] suggested mathematical formula and heuristics for the concept of maximum coverage. Their work was also for Omni-directional sensors. Ding et al. [7] suggested a power consumption reduction algorithm in coverage by interchanging sensors between active and sleep modes. They extended the network lifetime through non-disjoint coverage sets. Neishaboori et al. [8] worked on monitoring a collection of targets in a two-dimensional plane, which used homogeneous mobile pan-only cameras with a determined maximum angle of view and coverage limits. They stated an algorithm to find the minimum number of cameras, their locations, and directions, such that each target is visible by at least one camera. Their work is for stationary target only. Farzana et al. [9] work tackled the issue of obtaining the highest possible pair-wise disjoint cover sets in the VSN domain for directional sensors, their work dealt with static targets. This paper is addressing the problem of obtaining a pair-wise disjoint set cover with a minimum number of sensors for a random deployment of directional sensors to cover moving targets starts from random entry points reaching random exit ones. The rest of the paper is organized as follows: Section II presents a theoretical background; section III introduces the proposed system model; section V gives conclusions.

2. THEORETICAL BACKGROUND

The coverage problem in VSNs is more complicated as compared to the coverage problem in Wireless Sensor Networks (WSNs). It is coverage-based, target based, connectivity and lifetime. The camera's orientation has an effective role in the coverage problem of VSNs. The orientation determines the field of view (FoV) and it is the main factor for the coverage of the network. Figure 1 displays the field of view of a camera in the VSN. When the camera's orientation is changed, the coverage area of the VSN is also changed. If the cameras are properly mounted, a large area can be covered using a minimum number of them. The visual monitoring of the target area relies on the

nodes' posture, resolution and orientation of the camera [10], for a firm coverage of an area, the cameras must be mounted with a fixed focal lens. The nodes in WSNs can collect data only in its sensing range while cameras in VSNs can remotely capture images within its field of view.

Sensors gather data in a distinct manner for visual sensor networks, making a model of directional sensing. In addition, the final sensing and coverage can be influenced by certain elements of digital cameras, such as quality of lens and zoom capacities. While there are different options and settings, costs always restrict the quality and extra characteristics of visual sensors [11].



Field of View of Camera [10].

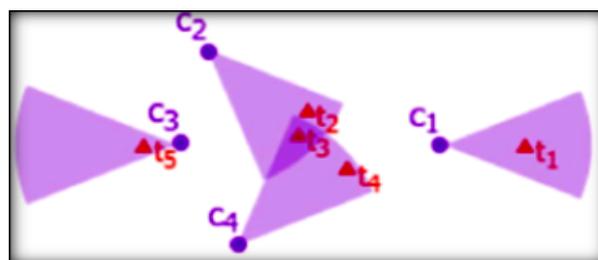
To cover a target, one can visualize two approaches:

- 1) Sensor-oriented approach.
- 2) Target-oriented approach.

During the first approach as shown in Figure 2, cameras can be examined and the precise coverage counts of each camera can be found in various spherical sectors. Depending on the coverage amount, iteratively pick cameras that can monitor the maximum number of targets. In the second approach as shown in Figure 3, one can look at the targets first instead of looking into the cameras. Some targets may be situated in a challenging corner of the region and could only be covered by the lowest number of camera sensors and critical sensors are the set of sensors that cover the critical target. One must prioritize the critical targets relying on their weakness in coverage and then choose a minimum set of camera cover targets according to their priorities [3,5,12,13].



Sensor-oriented approach [14].



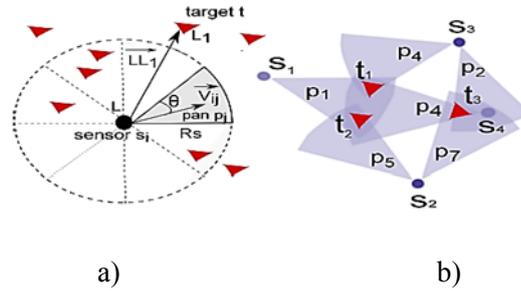
Target-oriented approach [14].

I. Directional Sensing Model

Unlike traditional sensing models where the sensor is based on an Omni sensing field, a directional sensing system is used as shown in Figure 4 a.

2-D sensing model, a sensor S_i of the sensing area is a sector symbolized by 4-tuple $(L, R_s, (V_{ij})^{\rightarrow}, \theta)$. L is the location of the sensor in a 2-D plane, R_s is the sensing range, $(V_{ij})^{\rightarrow}$ is the unit vector divides the sensing sector into half that defines the direction it is looking at, θ : is the cut off angle of (FoV) on both sides of $(V_{ij})^{\rightarrow}$ and Pan is the sensing sector for Pan Tilt Zoom camera sensors (PTZ).

Assume that a directional sensor might have limited non-overlapping pans set. For example, as depicted in Figure 4 a, a directional sensor with FoV, $2\theta = \pi/4$ can select 8 separated pans/orientations. These sectors can be joined to create an omnidirectional sensor's complete circular view [9, 14].



a) A directional sensor S_i of a bounded set of pans and the colored area is the existing sensing sector. b) Three targets $T = \{t_1, t_2, t_3\}$ and four directional sensors $S = \{s_1, s_2, s_3, s_4\}$. [9]

A sensor S_i located at position L is monitoring a target t at location L_1 when the following conditions are satisfied:

- 1) $d(L, L_1) \leq R_s$ where $d(L, L_1)$ is the Euclidian distance between the position of the sensor (L) and the target (L_1).
- 2) The resultant distance vector $(|LL_1|)^{\rightarrow}$ is within FoV $(-\theta, \theta)$ of the directional sensor $(V_{ij})^{\rightarrow}$ [9,14].

A simple way to determine if a target t is covered by sensor S_i in pan P_j if $(|LL_1|)^{\rightarrow} \leq R_s$ and $(LL_1)^{\rightarrow} \cdot (V_{ij})^{\rightarrow} \geq (|LL_1|)^{\rightarrow} \cdot (|V_{ij}|)^{\rightarrow} \cos \theta$.

Then the target t is coverable. Run the test for the whole targets, we can simply build a coverage matrix A_{ij}^t as that every element of the matrix, at ij , describes if the sensor s_i in pan p_j can monitor target t [9].

$$a_{ij}^t = \begin{cases} 1 & \text{if } (s_i, p_j) \text{ covers } t \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

The set of targets covered by a particular sensor pan pair (s_i, p_j) is indicated by Φ_{ij} and is defined by equ. 2:

$$\Phi_{ij} = \{t \mid a_{ij}^t = 1\} \quad (2)$$

For instance, in Figure 4 b

$$\Phi_{11} = \{t_1, t_2\} \text{ and } \Phi_{32} = \{t_3\}.$$

The set of sensor-pan pairs covering target t is denoted by $\Phi^{-1}(t)$ and is defined by relation (3):

$$\Phi^{-1}(t) = \{(s_i, p_j) \mid a_{ij}^t = 1\} \quad (3)$$

For example, in Figure. 4 b

$$\Phi^{-1}(t_1) = \{(s_1, p_1), (s_3, p_4), (s_4, p_4)\}$$

Cardinality of a target: The number of sensors pan pairs covering a target (t) is represented as cardinality $D(t)$ of the target (t) and is defined by Eq. (4):

$$D(t) = |\Phi^{-1}(t)| = |\{(s_i, p_j) \mid a_{ij}^t = 1\}| \quad (4)$$

A critical target is the target with minimal cardinality by definition 4 [9].

II. Disjoint coverage

According to a finite set of T targets for a W collection of T subsets, define if S can be categorized into two sets cover with no mutual element, and these set covers must cover all set elements completely.

III. Maximum Disjoint Set Cover Problem (MDSC)

The problem is called a maximum disjoint set cover problem or MDSC and is defined as follows: Assume a set of targets $T = \{t_1, t_2, \dots, t_m\}$. A set of homogeneous directional sensors $s = \{s_1, s_2, \dots, s_n\}$ within a set of non-overlapping pans $p = \{p_1, p_2, \dots, p_q\}$. Assume, each sensor S_i is directed in pan p_j covers a subset of targets $\Phi_{ij} \subset T$. As an interesting issue is in covering the whole targets, a set cover CK is defined as a group of sensor-pan pairs (s_i, p_j) that cover all the targets together. [9,14,15] i.e.:

$$\bigcup_{(s_i, p_j) \in C_k} \Phi_{ij} = T \quad (5)$$

Many coverage algorithms can be classified according to their characteristics and design choice of sensors:

1. Centralized Coverage Algorithms. The Base station analyzes the monitoring schedule first and for execution, it is sent to the sensor nodes.
2. Distributed Coverage Algorithms. Some sensor nodes perform considerably the required calculation and send scheduling information to various network sensors.
3. Localized Coverage Algorithms:

Each node runs the algorithm independently based on the information collected. [16].

3. PROPOSED SYSTEM MODEL

I. Modified Iterative Target Oriented Algorithm (MITOA)

The most common centralized coverage algorithms tackled the issue of finding the maximum coverage of targets is:

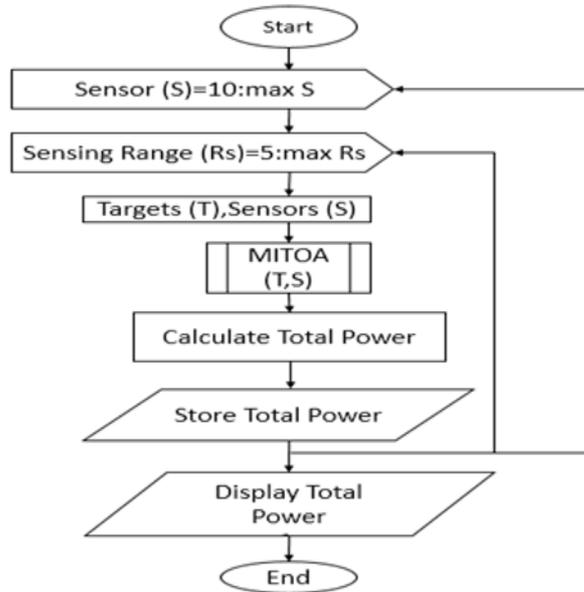
1. Iterative Centralized Greedy Algorithm (ICGA).
2. Iterative Centralized Force-directed Algorithm (ICFA).
3. Iterative Target-Oriented Algorithm (ITOA).

Both ICGA and ICFA first look at the sensors and pick the highest contributing sensor-pan sets. However, ITOA is concentrating on the targets. Through each iteration, it picks the lowest covered target and chooses to cover it by the sensor-pan pair. If there are more than one critical targets, then ITOA provides a set of critical targets with the same minimal cardinality and a list of sensor-pan pairs covering at least one of them. Then, ITOA chooses the most contributing sensor (the same as CGA) i.e. the sensor with a pan covering the maximum targets. Different from CGA, if more than one sensor has a similar maximal contribution, ITOA selects the one with the maximum force as in CFA. This method will be continued until every target is covered by at least one sensor creating a disjoint set cover. This section presents a sustainable scheme of the surveillance system, which is a modification of the existing ITOA and is designed using MATLAB Package R2017a (9.2.0.538062) under system specification in Table 1. MITOA is implemented first in a basic scenario and then various scenarios have been studied and designed to minimize the power consumption of this system in terms of network lifetime.

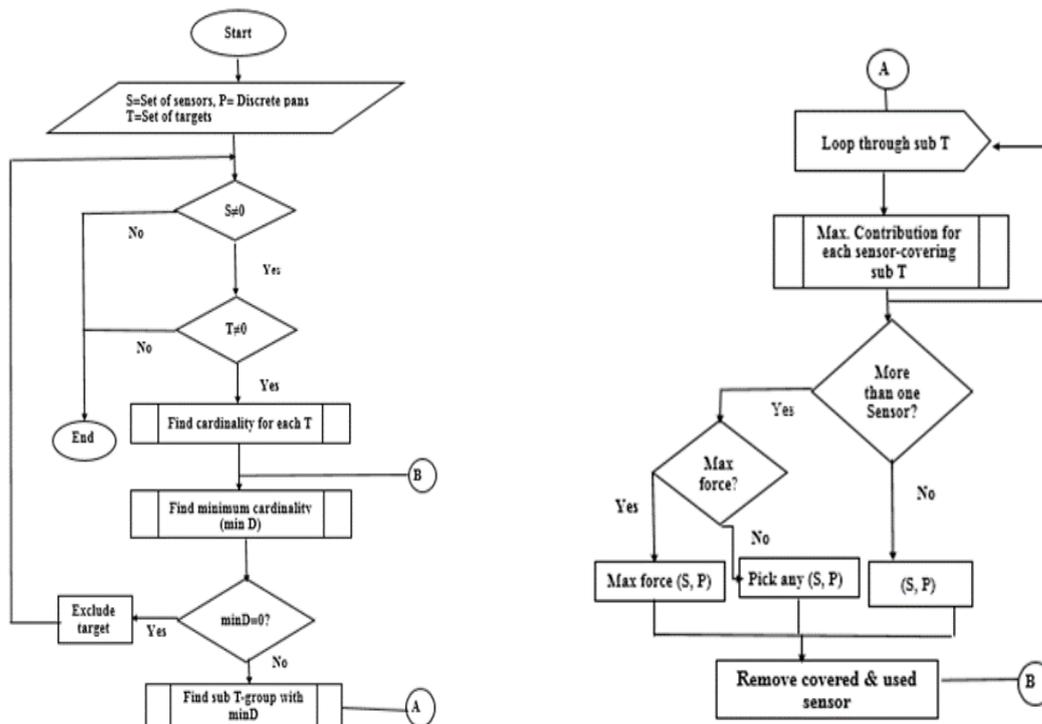
TABLE I: System Specification.

| | |
|-------------------------|--------------------------|
| Model | HP ProBook 4545s. |
| Processor | AMD A4-4300M APU. |
| Memory (RAM) | 8 GB. |
| System Type | 64-bit Operating System. |
| Operating System | Windows 7 Home Edition. |

ITOA had been designed to cover static targets in a random deployment of camera sensors, while MITOA was designed to cover targets move in random paths from entry points reaching to exit ones. Furthermore, ITOA stops computation of targets coverage in case of the targets set contains some uncovered targets, to overcome the problem, MITOA excludes them and continue computation for the rest of the targets to achieve maximum targets coverage. Figures 5-6 show the flowcharts of the sustainable system using the Target-Oriented Approach represented by Modified Iterative Target Oriented Algorithm (MITOA).



Sustainable System

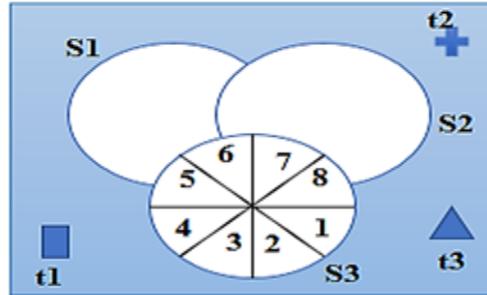


Flowchart of MITOA

4. RESULTS AND DISCUSSION

I. Basic Scenario

The basic scenario of the proposed surveillance system is presented in Figure 7.



Basic Scenario.

It is assumed a real-time scenario consists of three directional (PTZ) positioned in a random deployment and three moving targets move randomly over an area of (25 × 25) units. The model has a specified number of sensors and targets.

Suppose a homogenous system of sensors that means all camera sensors in the network have the same sensing ranges, the field of view, and energy level in the 2-D plane (x, y) in a Cartesian coordinates system.

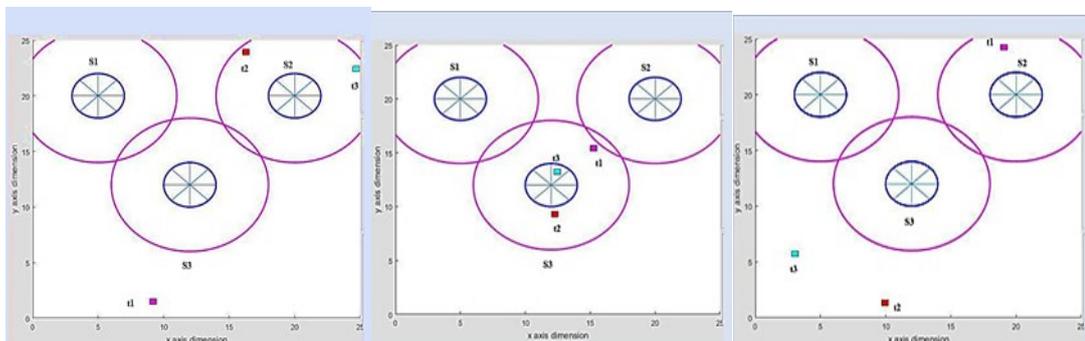
The following parameters in Table 2, are tuned in the simulation to observe the output:

TABLE II: Simulation Parameters.

| | |
|-----------|---|
| n | Number of camera sensors = 3, are positioned in random locations. |
| m | Number of moving target to be monitored, m=3, are randomly moved over the area. |
| Rs | Sensing range Rs is varied (from 5 to 15) units in step of two. |
| θ | Field of view angle = 45°. |
| q | Number of discrete non-overlapping pans which equals eight = (360/θ). |

- Assume the speed of a moving object equals the speed of a human being = 1.38 m/s.
- Pan (horizontal) movement of the lens is only considered.

The basic scenario of the network is composed of a specified number of target objects (m=3) starting from random entry points in terms of steps ending with random exit ones. The targets move randomly and the camera sensors (n=3) will cover them when they met the target in sector test (TIS) conditions. The MITOA Algorithm computes in Eq. (6) the power consumed by camera sensors in several sensing ranges varying from (5 to 15) units at each step of target movement. Figure 8 introduces several frames of experimental movement of targets covered by a specified number of camera sensors.



a) Start

b) Middle

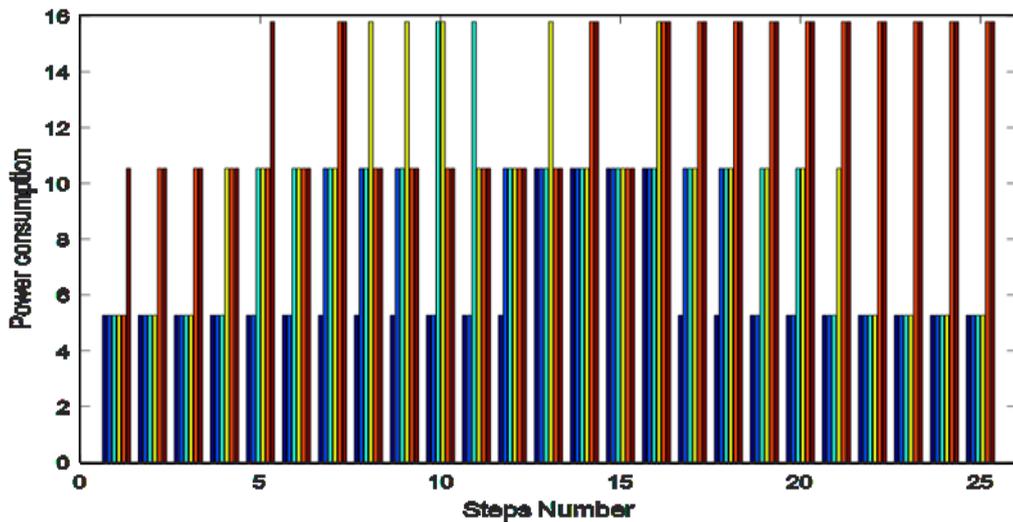
c) End

Targets movement

The basic scenario performance has been examined through two evaluation criteria:

1. Power consumption.
2. Network lifetime.

MITOA shows from results obtained in Figure 9, that the power consumed by the sustainable system is less than the old system does (when all camera sensors are in active mode all the time of monitoring before implementing the algorithm). The average power is minimized by generating a set cover with a minimum number of sensors covers the maximum number of moving targets move randomly in a real time scenario.



Power consumption after implementation of MITOA

Assume a Panoptes video sensor nodes used which consumes $p_i = 1.473W$ in idle mode, $p_a = 5.268W$ in active mode, and $p_s = 0.058W$ in sleep mode [19]. We could also partition the active power into dual sections. Power consumption for camera and network activation is about $p_{cn} = 4.28W$ and $p_{cr} = (5.268 - 4.28) = 0.988W$ when capturing the scene. The power consumption at $R_s=15$ is calculated according to Eq. (6).

$$P_{total} = N * P_c \tag{6}$$

Where

P_{total} : total consumed power

N: number of active sensors

P_c : power consumed of each camera

Therefore, the power consumed in the previous scenario is:

$$P_{total} = 63 * 5.268 = 331.884 \text{ w}$$

$$P_c = P_{total} / \text{no. of steps}$$

From results obtained, the targets move 25 steps from entry points to exit ones in a previous scenario, so that the power consumed is:

$$P_c = 331.884 / 25 = 13.27536 \text{ w} \cong 13.2754 \text{ w}$$

Table 3, has been presented to show the power saved from the implementation of the proposed system. This describes how much power is consumed and saved in each step the targets move for sensing range starting from (5-15) unit.

TABLE III: Active sensors at various Sensing range

| Step No. | proposed system | Total active sensors | Total all sensors |
|--------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|----------------------|-------------------|
| | Rs=5 | Rs=7 | Rs=9 | Rs=11 | Rs=13 | Rs=15 | | |
| 1 | 1 | 1 | 1 | 1 | 1 | 2 | 7 | 18 |
| 2 | 1 | 1 | 1 | 1 | 2 | 2 | 8 | 18 |
| 3 | 1 | 1 | 1 | 1 | 2 | 2 | 8 | 18 |
| 4 | 1 | 1 | 1 | 2 | 2 | 2 | 9 | 18 |
| 5 | 1 | 1 | 2 | 2 | 2 | 3 | 10 | 18 |
| 6 | 1 | 1 | 2 | 2 | 2 | 2 | 10 | 18 |
| 7 | 1 | 2 | 2 | 2 | 3 | 3 | 13 | 18 |
| 8 | 1 | 2 | 2 | 3 | 2 | 2 | 12 | 18 |
| 9 | 1 | 2 | 2 | 3 | 2 | 2 | 12 | 18 |
| 10 | 1 | 1 | 3 | 3 | 2 | 2 | 12 | 18 |
| 11 | 1 | 1 | 3 | 2 | 2 | 2 | 11 | 18 |
| 12 | 1 | 2 | 2 | 2 | 2 | 2 | 11 | 18 |
| 13 | 2 | 2 | 2 | 3 | 2 | 2 | 13 | 18 |
| 14 | 2 | 2 | 2 | 2 | 3 | 3 | 14 | 18 |
| 15 | 2 | 2 | 2 | 2 | 2 | 2 | 12 | 18 |
| 16 | 2 | 2 | 2 | 3 | 3 | 3 | 15 | 18 |
| 17 | 1 | 2 | 2 | 2 | 3 | 3 | 13 | 18 |
| 18 | 1 | 2 | 2 | 2 | 3 | 3 | 13 | 18 |
| 19 | 1 | 1 | 2 | 2 | 3 | 3 | 12 | 18 |
| 20 | 1 | 1 | 2 | 2 | 3 | 3 | 12 | 18 |
| 21 | 1 | 1 | 1 | 2 | 3 | 3 | 11 | 18 |
| 22 | 1 | 1 | 1 | 1 | 3 | 3 | 10 | 18 |
| 23 | 1 | 1 | 1 | 1 | 3 | 3 | 10 | 18 |
| 24 | 1 | 1 | 1 | 1 | 3 | 3 | 10 | 18 |
| 25 | 1 | 1 | 1 | 1 | 3 | 3 | 10 | 18 |
| sum n | 29 | 35 | 43 | 48 | 61 | 63 | 278 | 450 |

The accumulated time can be defined as the time required for executing the algorithm many times as specified per scenario and can be calculated as shown in Eq. (7):

$$T_{av} = T_{acc} / \text{nor} \quad (7)$$

Where

T_{av} : Average time.

T_{acc} : accumulated time.

nor: Number of repetitions of the modified algorithm.

$T_{av} = 0.72 / (6*25) = 0.0048 \text{ s} = 4.8 \text{ ms}$.

An important metric to evaluate the performance of MITOA is the Ratio of Total to Active Cameras Sensors used. RTA is a metric of camera usage. The higher the ratio the better the performance is. The fraction of the total number of cameras sensors to the Number of active cameras selected by the modified algorithm:

$$RTA = n_{\text{total}} / n_{\text{active}} \quad (8)$$

Where

n_{total} : Number of all camera sensors used.

n_{active} : Number of active sensors selected by the modified algorithm.

For instance, at Rs=15 as clarified in Table 3

$RTA = 3/2 = 1.5$ for each step, assume the network lifetime for step 1 of the target movement equals t then the network lifetime N.L equals:

$$N.L = RTA * t \quad (9)$$

$$N.L = 1.5 * t$$

The number of total camera sensors used for all steps of the basic scenario at any sensing range is $3 * 25 = 75$

At $R_s = 15$:

$$RTA = 75/63 = 1.190 \approx 1.2$$

$$N.L = 1.2 * t$$

The sensing range is varied from (5 to 15) units, the network lifetime of the basic scenario is calculated as follows:

$$RTA = 450/278 = 1.618 \approx 1.62$$

$$N.L = 1.62 * t$$

As a result of these calculations, the MITOA shows that the network lifetime increased when a disjoint set cover is generated having a minimum number of active camera sensors cover a maximum number of moving targets.

In other words $N.L \propto RTA$. To test the effect of increasing the sensing range on the network lifetime, Eq. (8) and Eq. (9) are applied for all sensing ranges and a network lifetime $t = 1$, it is noticed from results obtained that the network lifetime has been reduced. Increment of R_s , the PTZ camera's lens is concentrated at a range reflecting the increment in depth-of-field of FoV and will cover more targets that mean it will be active for a longer time, which acquires more power consumption. Results of the Sensing range vs. Network lifetime are shown in Table 4. The network lifetime will be as shown in Figure 10:

TABLE IV: Sensing range vs. Network lifetime.

| R_s | N. L |
|-------------------------|-------------|
| 5 | 2.58 |
| 7 | 2.14 |
| 9 | 1.74 |
| 11 | 1.56 |
| 13 | 1.23 |



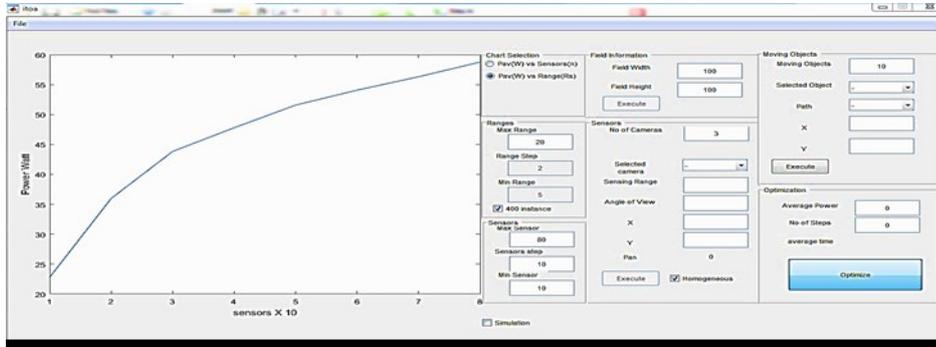
Sensing range vs. Network lifetime.

II. Major Scenario

The main scenario is generated to compare the MITOA algorithm with three existing Algorithms (ICGA, ICFA and ITOA) by applying the same environment. The dimensions of the basic scenario of the monitored area are varied to (100×100) units, the number of randomly deployed sensors starts from (10-80) with an increment of 10 to cover a fixed number of targets $m = 10$ and fixed $R_s = 20$ units. In addition, the sensing range starting is varied from 14 units ending with 30 units in the step of (2) unit while keeping the number of discrete pans constant to (8) to evaluate the effect of increasing the sensing range of directional camera sensors. The target number is retained fixed to 10; move randomly over an area to be covered. The VSN is randomly created for a certain value of sensors; moving targets and sensing range, the solution along with the MITOA algorithm is simulated over

the VSN. For each size of VSN, 400 instances are produced over which the simulations are carried out. Performance measurements are recorded as an average of 400 random scenarios. For evaluation of the performance, two approaches are followed through simulation:

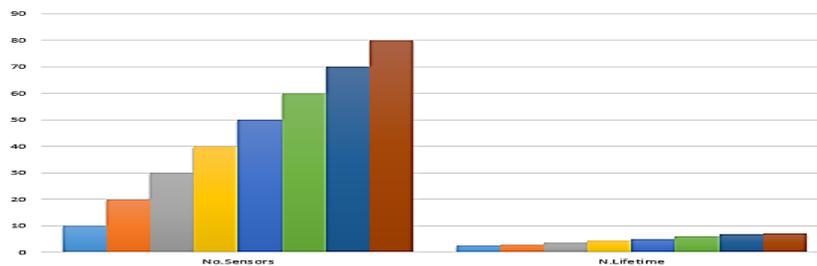
1. Varying no. of sensors n while keeping no. of moving targets m and the sensing range R_s constant.
2. Varying R_s while keeping no. of sensors n and no. of moving targets m constant.



power consumption vs. no. of sensors (m=10).

TABLE V: Results of network lifetime for (10-80) sensors.

| No.total sensors | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| $P_{av} (w)$ | 22.80 | 35.96 | 43.82 | 47.77 | 51.57 | 54.06 | 56.30 | 58.75 |
| Active Sensor | 4 | 7 | 8 | 9 | 10 | 10 | 11 | 11 |
| RTA | 2.5 | 2.85 | 3.75 | 4.44 | 5 | 6 | 6.36 | 7.27 |



Relationship between no. of sensors and network lifetime.

Figure 12 shows the effect of an increasing number of sensors on the network lifetime. The network lifetime is extended with the increasing number of sensors. MITOA minimizes the power consumed by sensors because it generates a disjoint set cover of minimum camera sensors that monitors the maximum number of targets. Y-axis as in Figure 11 and Table 5 shows the amount of power consumed as an average of 400 random scenarios.

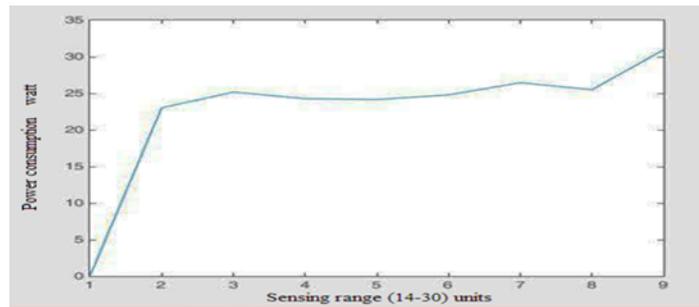
The sustainable system is moving from the under-provisioned system to the over-provisioned since at the beginning, there are not sufficient cameras to monitor all the targets. Adding extra camera sensors leads more cameras to be enabled as the algorithm maximizes the coverage of the target. Hence, the power consumption increases. After some stages when the system becomes over-provisioned, the power consumption decelerates as at that stage, all targets are covered and no more cameras get enabled. Therefore, the newly added sensors last unused at sleep mode resulting in a small increase in overall power consumption.



Average power consumption comparison between ITOA, ICFA, ICGA and MITOA.

N= (10-80), Rs=20 unit, m=10

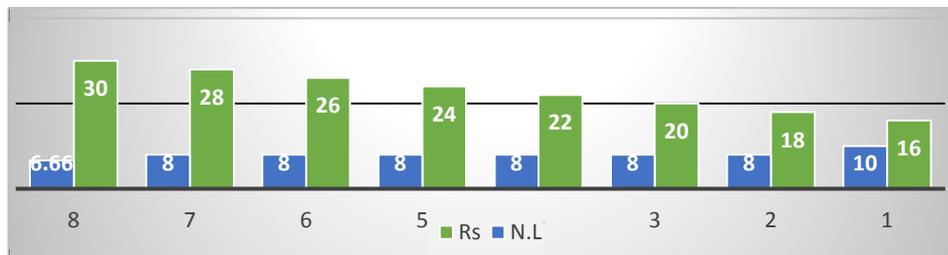
Figure 13, exhibits an average of all four algorithms of power consumption. The same parameters have been taken to compare the performance of the four algorithms. ICGA, ICFA and ITOA show the least amount of power consumption compared to modified algorithm MITOA. Steadily, the power consumption of ICGA and ICFA rises as their sensor ratio increases, but the solutions do not increase by that ratio. On the other side, ITOA significantly increases set-cover numbers while minimizing the number of active sensors in every set. MITOA maximizes the coverage for moving targets and instead of ending computation in case of uncovered targets, it excluded them and continue computation to reach maximum coverage. The use of a realistic scenario of moving targets implies a small number of sensors will detect the incoming and exiting targets, which gives MITOA a better chance to pick the minimum number of sensors. Therefore, it consumes less power than ICFA and ICGA when the sensor density is large.



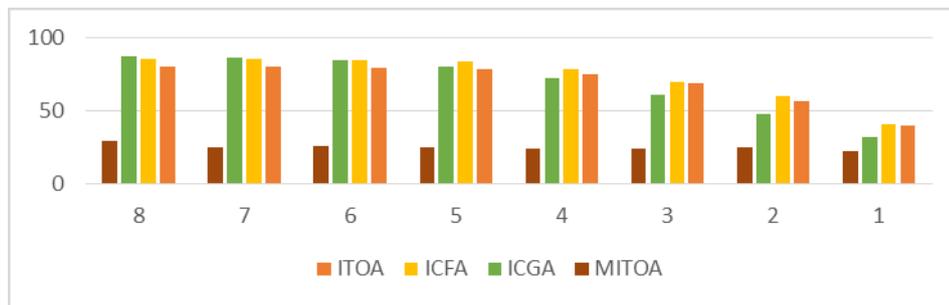
Average power consumption vs. Sensing range (n=40).

The greater the sensing range of camera sensors, the greater the power consumed because extra moving targets will be covered and the camera sensors will remain working longer as presented in Figure 14. MITOA consumes power less than ICGA, ICFA, and ITOA due to different movements and directions the moving targets follow in the given area as previously explained.

As a result, the network lifetime is reduced as shown in Figure 15.



Sensing range vs. Network lifetime.



Average power consumption comparison between ITOA, ICFA, ICGA and MITOA. Rs= (15-30) units, n=40, m=10

Figure 16 shows MITOA consumes less power than ICGA, ICFA, and ITOA but requires a longer time to implement due to different movements and directions the moving targets follow in the given area and thus increases the computational processing.

5. CONCLUSIONS

This paper addressed one of the main challenges' issues of VSNs design known as the converge problem. The aim of the current work is to build an energy-efficient system to extend the network lifetime. A graphical user interface was designed to simulate the operations of the proposed system. The simulation results showed some essential worth of mentioning points as follows:

1. MITOA algorithm generates a disjoint set cover while reducing the number of used sensors. Therefore, when sensor density is high, many redundant nodes have existed, the system consumes less power, and thus the lifetime of the network is extended.
2. It is noticed that the high increase of sensors does not significantly affect the enhancement of power consumption due to deterioration occurred and as a result, the cost of design will be acceptable.
3. The MITOA Algorithm excludes uncovered targets and continues computation to achieve maximum coverage of moving targets in a real-time simulation, which results in a better execution than stopping computations in conventional ITOA algorithm.
4. Simulation results reveal that the sustainable system can find a disjoint set with a minimum number of sensors, which cover the maximum number of moving targets in an energy-efficient way and extended network lifetime.

References

- [1] Y. Xiong, J. Li, and M. Lu, "Critical location spatial-temporal coverage optimization in visual sensor network," *Sensors (Switzerland)*, Vol. 19, No. 19, pp. 1–14, 2019.
- [2] M. Cardei and B. Raton, "Energy -Efficient Target Coverage in Wireless Sensor Networks," *Proceedings - IEEE INFOCOM 16(5):1976 - 1984 vol. 3 · April 2005* .
- [3] J. Ai and A. A. Abouzeid, "Coverage by directional sensors in randomly deployed wireless sensor networks," *J. Comb. Optim.*, vol. 11, no. 1, pp. 21–41, 2006.
- [4] Yanli Cai, Wei Lou, Minglu Li, and Xiang-Yang Li, "Energy Efficient Target-Oriented Scheduling in Directional Sensor Networks," *IEEE Trans. Comput.*, vol. 58, no. 9, pp. 1259–1274, 2009.
- [5] V. P. Munishwar and N. B. Abu-Ghazaleh, "Target-oriented coverage maximization in visual sensor networks," p. 175, 2011.
- [6] N. Ahn and S.Park, "A New Mathematical Formulation and a Heuristic for the Maximum Disjoint Set Covers problem to Improve the Lifetime of the Wireless Sensor Network", vol. 13, pp209-225, 2011.
- [7] L. Ding, W. Wu, J. Willson, L. Wu, Z. Lu, and W. Lee, "Constant-approximation for target coverage problem in wireless sensor networks," *Proc. - IEEE INFOCOM*, pp. 1584–1592, 2012.

- [8] A. Neishaboori, A. Saeed, K. A. Harras, and A. Mohamed, "Low complexity target coverage heuristics using mobile cameras," Proc. - 11th IEEE Int. Conf. Mob. Ad Hoc Sens. Syst. MASS 2014, pp. 217–221, 2015.
- [9] S. Farzana, K. A. Papry, A. Rahman, and R. Rab, "Maximally pair-wise disjoint set covers for directional sensors in visual sensor networks," IFIP Wirel. Days, vol. 2016-April, no. iv, 2016.
- [10] R. Sharma, "Traits of visual sensor networks," Proceedings of the International Conference on Inventive Research in Computing Applications (ICIRCA) IEEE Xplore Compliant Part Number: CFP18N67-ART; July, 2018.
- [11] D. G. Costa and L. A. Guedes, "The coverage problem in video-based wireless sensor networks: A survey," Sensors, vol. 10, no. 9, pp. 8215–8247, 2010.
- [12] H. Gupta, Z. Zhou, S. Member, S. R. Das, and Q. Gu, "Connected Sensor Cover : Self-Organization of Sensor Networks for Efficient Query Execution," vol. 14, no. 1, pp. 55–67, 2006.
- [13] V. P. Munishwar and N. B. Abu-Ghazaleh, "Coverage algorithms for visual sensor networks," ACM Trans. Sens. Networks, vol. 9, no. 4, 2013.
- [14] H. Zannat, T. Akter, M. Tasnim, and A. Rahman, "The coverage problem in visual sensor networks: A target oriented approach," J. Netw. Comput. Appl., vol. 75, pp. 1–15, 2016.
- [15] M. F. Abdulhalim and A. Attea, "Multi-layer Genetic Algorithm for Maximum Disjoint Reliable Set Covers Problem in Wireless Sensor Networks," 2004.
- [16] R. Deepa, R. Venkataraman, M. Pushpalatha, and P. T. Ravichandran, "A review on cover set problem in wireless sensor networks," J. Adv. Res. Dyn. Control Syst., vol. 9, no. 8, pp. 151–161, 2017.
- [17] R. A. Hamamreh, "An Energy-Efficient Clustering Routing Protocol for WSN based on MRHC," Int. J. Digit. Inf. Wirel. Commun., vol. 8, no. 3, pp. 214–222, 2018.
- [18] S. Soro and W. B. Heinzelman, "On the coverage problem in video-based wireless sensor networks," 2nd Int. Conf. Broadband Networks, BROADNETS 2005, vol. 2005, pp. 9–16, 2005.
- [19] W. C. Feng, E. Kaiser, W. C. Feng, and M. Le Baillif, "Panoptes: Scalable Low-Power Video Sensor Networking Technologies," ACM Trans. Multimed. Comput. Commun. Appl., vol. 1, no. 2, pp. 151–167, 2005.