Optimizing the Light Trap Position for Brown Planthopper (BPH) Surveillance Network

Huong Hoang Luong[1(✉)], Tuyen Phong Truong[2], Ky Minh Nguyen[3], Bao Hoai Lam[4], and Hiep Xuan Huynh[5]

[1] CUSC-CTU, Cantho, Vietnam
lhhuong@ctu.edu.vn
[2] Universite de Bretagne Occidentale, Brest, France
tptuyen@ctu.edu.vn
[3] Can Tho University of Technology, Cantho, Vietnam
nmky@ctuet.edu.vn
[4] CICT-CTU, Cantho, Vietnam
lhbao@cit.ctu.edu.vn
[5] DREAM-CTU/IRD, CICT-CTU, Cantho, Vietnam
hxhiep@ctu.edu.vn

Abstract. To forecast the population of brown planthopper (BPH), a major insect pest of rice in Mekong Delta in Viet Nam, a light trap network is used in the experiments where the BPH trapped density is considered as monitoring called BPH light trap surveillance network (BSNET). There are two problems in order to deploy the BSNET: the number of the light traps and their positions. In this paper, we propose a new approach to optimize the BSNET by determining the number of light traps needed and the position for every light trap node in the surveillance region based on **HoneyComb** architecture. The experiment results are performed on the Brown Planthoppers surveillance network for Mekong Delta in Viet Nam.

Keywords: Light trap · BPH · Surveillance Network · Optimization · Optimal-design · HoneyComb

1 Introduction

The light trap surveillance network [1] in Mekong Delta region is one kind of representative sampling applying for the geographical region. The light trap surveillance network that can capture multiple kinds of insects, especially BPH, and which data (the density of insects per trap) is collected and analyzed daily. The light trap surveillance network is deployed in the experiments where the BPH trapped density is considered as monitoring called BPH light trap surveillance network (BSNET). BSNET is a spatial sampling network applying for the geographical region.

Automatic light trap [2] consists of autonomous sensors to monitor environment conditions such as temperature, sound, and so on. The automatic light trap

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can pass their data to the others. The BSNET is considered as a automatic light trap surveillance network. To deploy the BSNET, there are two factors need to consider including where the light trap is localized and the number of the light trap needed.

In this paper, we propose a new approach to optimize the light trap position for BPH surveillance network. The approach in use is the honeyComb architecture [3] to determine the light trap position with minimum the number of light traps needed.

This paper contains 7 sections. Some related works are introduced in the next section. Automatic Brown PlantHopper surveillance network is presented in the Sect. 3. Section 4 will describe how to optimize the light trap position for Brown PlantHopper surveillance network (OBSNET) and the OBSNET implementation is presented in Sect. 5. Section 6 will introduce some experimental results by applying the new approach. The last section summarizes the contribution and suggests some researches in the future.

2 Related Works

The surveillance network is applied in many domain of environment and ecological research such as in the agricultural management [4], in the fishery surveillance, and in the forest management [1,5]. Light traps are used to monitor the kinds of insect in the agricultural such as BPHs.

Optimal design is a kind of the experiment design that affects respect to some statistical criteria [1,6,7]. Many optimal designs proposed are A-optimal design, D-optimal design, and E-optimal design [7].

Optimization for wireless sensor network or particular light trap network is an important research. In fact, there are many related researches such as layout optimization [8], optimization for energy [9], optimization for coverage - connectivity - topology... [10], schemes optimization [11], optimizing for environment surveillance network [12], and etc. [13–15].

In optimal design, optimization for location wireless sensor network or light trap network that ensures the network is coverage or connectivity and so on, which is a popular research. Many researches for that are presented in [10,12,16–18]

The Unit Disk Graph (UDG) technique was introduced by Clark [19] and has been used widely in ad-hoc communication. In this model, a sensor device is a node where and edge between two nodes is established if the distance between them is at most the disk radius r. There aren't many investigations of UDG in manage an ecosystem. Some researches based on UDG for estimating the BPH density and modeling the surveillance network were introduced in [20,21].

The HoneyComb architecture [3] is applied in wireless and mobile communication. Many research such as optimization the location for base transceiver station, virtual infrastructure for data dissemination in multi-sink mobile wireless sensor network and so on are proposed in [22,23]

3 Automatic Brown PlantHopper Surveillance Network

3.1 Automatic BPH Light Trap

The light trap [24] is one kind of passive trap helping to catch only the mature insects, and it operates only at night. A light trap uses light as an attraction source [25]. Light traps depend on the positive phototactic response of the insects, physiological as well as abiotic environmental factors which can influence the behavior [26]. Many kinds of insect will be caught and counted every day to observe the current density of them. BPH monitoring process is done manually.

To automate the process of monitoring BPHs, a network of automatic BPH light traps need building. An automatic BPH light trap includes some functions such as detecting the BPHs and counting the number of BPHs in the trap. Also, the automatic BPH light trap can transmit data to other(s).

An automatic BPHs light trap [2] was equipped with light source, tray, a camera, communication devices, some sensors and a power. The camera is programmed to capture the images from tray. Also, it can recognize the BPHs and count the number of BPHs in the image. The sensors includes temperature, light, humidity, wind speed and wind direction. The communication devices which use radio are used to transmit or receive data.

3.2 Automatic BPH Light Trap Surveillance Network

A automatic BPH light trap surveillance network is a graph *G=(V, E)*. This graph built from a set of vertices $V = \{v_1, v_2, ..., v_n\}$ and the set of edges $E = \{e_1, e_2, ..., e_m\}$. The vertice v_i with $i \in \{1..n\}$ is an automatic light trap. The edge e_k with $k \in \{1..m\}$, $i \in \{1..n\}$, $j \in \{1..m\}$ is an edge between two vertices v_i and v_j. The weights of the edges are defined by W=$\{w_1, w_2, ..., w_m\}$ where the value of w_k is given by distance function $f_d(v_i, v_j)$.

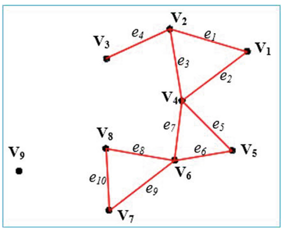

Fig. 1. A light trap network is presented as a graph (Color figure online)

Figure 1 illustrates the logical graph of a light trap network where the black dots mean the vertices in V and the red lines mean the edges in E. The graph contains 9 vertices $V = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9\}$ and 10 edges $E = \{e_1 = e(v_1, v_2), e_2 = e(v_1, v_4), ..., e_9 = e(v_6, v_7), e_{10} = e(v_7, v_8)\}$.

Each node of light trap network has a communication range that is indicated by a circle with radius r. Conditions to define existence of an edge are introduced as following:

Definition 1 (Established edge). An edge is established if and only if the distance between a pair of vertices is less or equal to the minimum value of their radius - $f_d(v_i, v_j) \leq min(r_i, r_j)$.

Definition 2 (Unestablished edge). An edge is not established if distance between a pair of vertices is greater than the minimum value of their radius - $f_d(v_i, v_j) > min(r_i, r_j)$.

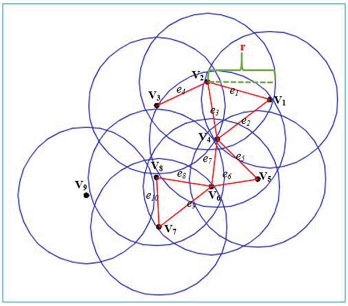

Fig. 2. The communication range of light traps that is used to establish the edges between the light traps

In the Fig. 2, the graph contains 1 subgraph and an isolated node. The sub graph consists of 8 nodes since distances among these nodes are less than the radius r while the vertex v_9 is an isolated node because all distance values between it to others are insufficient to the Definition 1.

To deploy the automatic BPH light trap surveillance network, we need to consider the positions where to place the automatic light traps so that the number of light traps is minimum. In the next section, we will present a new approach to optimize the light trap position for BPH surveillance network (The light trap network which is created by using this approach is called *Optimized BPH Surveillance Network*, contracted *OBSNET*).

4 OBSNET

4.1 Optimization for Surveillance Network

The BSNET will be deployed in regular pattern. The pattern can be a hexagon grid or triangular lattice [27]. In [28], this paper specifies for each pattern a condition that ensures the coverage of the region and guarantees network connectivity [27,29–34]. If R $\geq$ r and $0 \leq \frac{R}{r} \leq \frac{1}{2}3^{\frac{3}{4}}$, the hexagonal grid is the best deployment, it ensured the region is full coverage, the network is connected and it requires the minimum number of light trap nodes. Otherwise, if R $\geq \sqrt{3}$r, the triangle lattice is the optimal deployment pattern to ensure full region coverage and network connectivity.

For simplicity, triangular lattice is used to build surveillance network. The construction of this method is initiated by placing a light trap in the center of surveillance region. The others will be set based on the first light trap. For example, the first light trap is located at (x,y) in Euclidean space, the neighbor light traps are located at (x,y$\pm\sqrt{3}$r), and (x$\pm$1.5r, y$\pm\frac{\sqrt{3}r}{2}$). Through the recursive this construction, we not only determine the position for all the light traps in the surveillance region with the minimum number of the light traps but also ensure the surveillance region that is full coverage about the communication.

There are two cases in the deployment of OBSNET. In the first case, the deployment region will be divided into smaller units based on some conditions such as river, road, province, district and so on. After that, the biggest unit will be considered and hexagon cell at this unit will be created. Also, a hexagon grid will be created based on the first hexagon cell. The light traps will be located at the center of the hexagon cell. The pseudo-code for this case is presented in Algorithm 1.

Algorithm 1. OBSNET with the first case

```
begin
    Divide deployment region into smaller unit;
    Get the biggest unit;
    Let w is the width of the biggest unit;
    Let c is center coordinates of the biggest unit;
    list<hexagon> ⟵ hexagonGridBuilder(c,w);
    list<lighttrap> ⟵ lighttrapBuilder(list<hexagon>);
    network<lighttrap> ⟵ honeyCombNetworkBuilder(list<lighttrap>);
    return network<lighttrap>;
end
```

In the second case, a hexagon grid will be created by using the same method of the first case. If there are more than an unautomated light traps in a hexagon cell, build the unautomated light trap which is nearest from center of the hexagon cell to become the automatic light trap. After that, if the BSNET is not connected or not covered the deployment region about the communication, a light trap will be added at the center of the blank hexagon cell. Then, the connectivity will be checked again. If the BSNET is still not connected, move the light trap in the hexagon cell which is not connected with the honeycomb network to the center of that hexagon cell or intersection of communication range between two automatic light traps (choose the nearest point). The pseudo-code for the second case is presented in Algorithm 2.

Algorithm 2. Create a honeyComb network on deployment region with existing light traps

```
begin
    Divide deployment region into smaller unit;
    Get the biggest unit;
    Let w is the width of the biggest unit;
    Let c is center coordinates of the biggest unit;
    list<hexagon> ⟵ hexagonGridBuilder(c,w);
    foreach cell in the list<hexagon> do
        if There are more than unautomated light trap in a hexagon cell then
            Build the nearest unautomated light trap from center to automatic
            light trap;
        end
    end
    Build the automatic light trap network;
    repeat
        if automatic light trap network is not connectivity then
            Find all isolated light trap;
            repeat
                foreach every isolated light trap do
                    Move it to center of hexagon cell or intersection of
                    communication range between two automatic light trap;
                end
            until automatic network is connectivity;
        end
        if automatic light trap network is not coverage then
            foreach cell in hexagon list do
                if no light trap in a cell then
                    Create a light trap at the center of the cell;
                end
            end
        end
        Build the automatic light trap network;
    until automatic light trap network is connectivity and coverage;
    return the automatic light trap network;
end
```

4.2 OBSNET Implementation

There are many factors that effect the implementation of the OBSNET. In this scope, we present the basic factors that effect the implementation of the OBSNET. Each factor has attributes and behaviors to interact each other.

Main factors are province, district, commune, light trap, and hexagon cell. When a map data is loaded, the commune factor will be created automatically and has certain attributes such as code, name, and area (Fig. 3). Each district

```
species commune{
    string ID_commune;
    string name_commune;
    string ID_district;
    rgb color <- #white;
    float area <- 0.0;
}
```

Fig. 3. A definition of commune

```
species hexagon{
    float size <- 0.0;
    point center;
    float range <- 0.0;
    list<hexagon> neighbors;
    rgb color <- #red;
}
```

Fig. 4. A definition of hexagon grid

factor knows which commune factor it includes. A hexagon grid includes attributes such as coordinate of center, radius and its neighbors as in Fig. 4.

5 Experiment

5.1 Case Study: Mekong Delta Region

Mekong Delta has 13 provinces. Every province is divided into smaller regions called districts. A district is also divided into smaller regions called communes. The Mekong Delta region can be considered as a surveillance region where need deploying the automatic light traps to monitor the BPHs. The region is divided as a grid of hexagonal cells. A cell is the smallest unit in this region and it is considered as a commune in Mekong Delta. Every cell has 6 neighbors. Each cell has the same width and height in the implementation. In other words, each cell has the same radius. The radius is considered from biggest commune in the surveillance network. The automatic light traps are located in the center of the cell. The HoneyComb network for Can Tho province is presented in the Fig. 5.

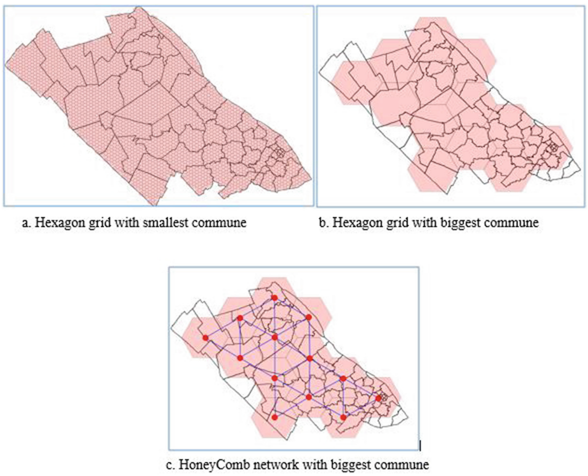

Fig. 5. OBSNET in a province of Mekong Delta region

5.2 Data Used

The data of experiment is a GIS map data of the *Hau Giang* province at administrative levels including province, district, and commune. The data is stored as a table includings id, name (province, district, commune), shape length, shape area and so on (Fig. 6).

id_province	name_province	id_district	name_district	id_commune	name_commune	type	shape_leng	shape_area
38254	Hau Giang	103164	Chau Thanh	34429	Nga Sau	Townlet	0.142665	0.00088672
38254	Hau Giang	103164	Chau Thanh	34428	Dong Thanh	Commune	0.172407	0.00093227
38254	Hau Giang	103164	Chau Thanh	34427	Dong Phuoc A	Commune	0.200755	0.00139623
38254	Hau Giang	103164	Chau Thanh	34426	Dong Phuoc	Commune	0.209359	0.00180681
38254	Hau Giang	103164	Chau Thanh	34432	Phu Huu	Commune	0.165654	0.00142994
38254	Hau Giang	103164	Chau Thanh	34433	Mot Ngan	Townlet	0.130744	0.00067739

Fig. 6. Data of Hau Giang province

The position of the light traps are stored in the plain text with xml format (*.gpx) that are used as input data. Figure 7 presents the structure of the data with three types of information including date, coordinate of the light trap (longitude, latitude), and name. This file is created by using NetGen platform (a platform is developed by Brest university - France) [35]. Also, an abstract network of the light traps for BPH surveillance region at *Hau Giang* province was generated from NetGen [35].

```xml
<?xml version="1.0"?>
<gpx version="1.0" creator="NetGen for Hau Giang">
  <metadata>
    <name>Hau Giang's sensors</name>
    <desc>Sensors in city: Hau Giang, Vietnam</desc>
  </metadata>
    <wpt lat="9.957438" lon="105.743126">
        <sym>sound</sym>
        <cmt>title1</cmt><time>2013-031916:02:42</time>
        <name>Node:60</name>
        <desc>Noise:</desc>
    </wpt>
```

Fig. 7. The position of the light traps in the xml format

5.3 OBSNET Tool

We have developed the OBSNET tool in GAML [36] that enables to optimize the number of the light traps needed and their positions. OBSNET tool enables to show the gis map data, determine the position of the light trap on a map, create and display a hexagon grid on map, and build the honeycomb network. Besides, OBSNET tool is also used to determine the communication range for automatic light trap based on honeyComb network.

5.4 Experiment 1: Optimizing the Light Trap Position for BPH Surveillance Network on the Surveilance Region Without Existing Unautomated Light Trap

The requirement for this experiment must create a honeyComb network for Hau Giang province. First, the experiment will display the gis map data of Hau Giang province as communes. Then, it will determine the biggest commune on the map and construct the hexagon grid based on that commune. The result shown as Fig. 8.

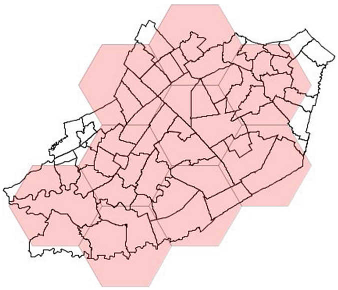

Fig. 8. Hexagon grid for Hau Giang province

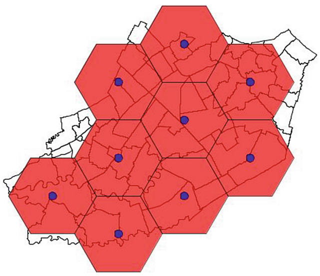

Fig. 9. Light trap position in hexagon grid for Hau Giang province (Color figure online)

In Fig. 8, we obtain a hexagon grid with 9 hexagons. Each hexagon has a radius with 8.842 (m). Therefore, the minimum communication range is proposed $8.842 * \sqrt{3} = 15.315$ (m). After building the hexagon grid, place a automatic light trap at the center of hexagon (blue circle). The result shown as Fig. 9. The communication range of the automatic light trap is shown as yellow circle (Fig. 10)

5.5 Experiment 2: Optimizing the Light Trap Position for BPH Surveillance Network with Existing Unautomated Light Trap

In this experiment, we will build the hexagon grid on the surveillance region that have some existing unautomated light traps. First, we need to consider to build some unautomated light traps to become automatic light traps. Second, we will build the honeyComb network. If the network is not connected (there are some isolated automatic light traps), these automatic light traps will be considered moving to a new location. The hexagon grid on the surveillance region with existing unautomated light trap is shown as in Fig. 11. There are two cases about the unautomated light trap position. They are the unautomated light trap is located inside or outside the hexagon grid.

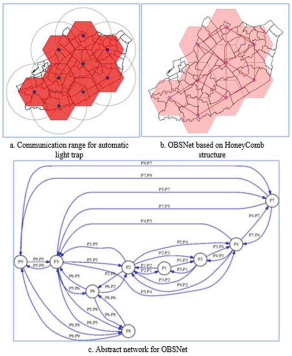

Fig. 10. The OBSNET for the automatic light traps in Hau Giang (Color figure online)

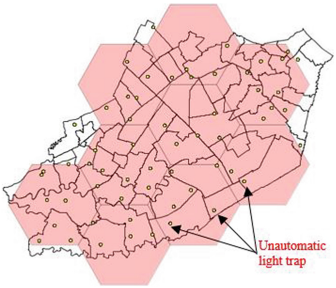

Fig. 11. The hexagon grid on Hau Giang with existing non-auto light traps

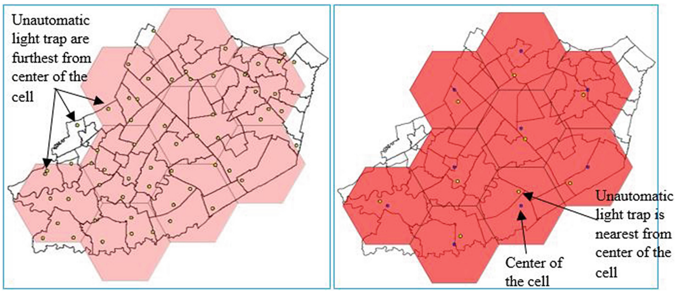

Fig. 12. Get unautomated light trap is nearest from center of the hexagon cell

Then, skip all the unautomated light traps outside the hexagon grid. After that, we will traverse every hexagon cell in hexagon grid, and get the unautomated light trap nearest from the center of the cell and skip all the others. The result is shown as in Fig. 12

The nearest unautomated light traps from center of the hexagon cell will become an automatic light trap with communication range that is calculated in

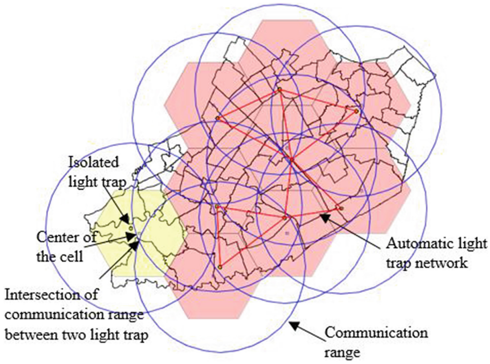

Fig. 13. Skip the unautomated light trap

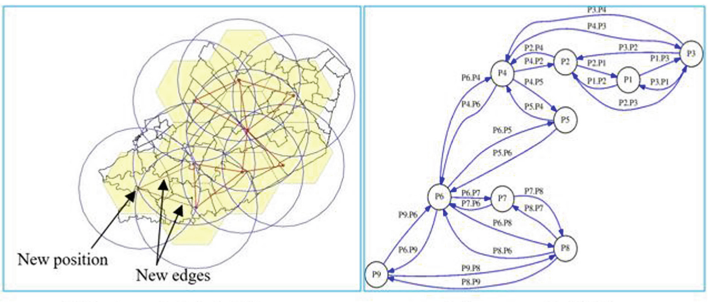

Fig. 14. OBSNet is built after moving the isolated automatic light trap to new position

the experiment 1. Now, we will build the honeyComb network for the automatic light traps (Fig. 13).

In the Fig. 13, there is an isolated automatic light trap, so the network is not connected. Therefore, we must move the isolated to new position that helps the network connect. There are two new positions including the center of the cell and the intersection between two communication of two automatic light traps in neighbor cells. In this experiment, we will choose the nearest position that helps network connect. It is the intersection between two communication ranges.

The Fig. 14 shows the network after moving the isolated light trap to new position (intersection between two communication ranges of two automatic light traps).

6 Conclusion

The research on the optimization the light trap position for surveillance network is one of the important trends in the environment and ecological research. This trend solves some questions such as where light traps are placed, how to fully cover the surveillance region and so on. Therefore, we propose a new approach to optimize the light trap position for BPH surveillance network based on honeyComb structure.

Building the hexagon grid and honeyComb network helps to determine the number of light traps needed and their positions. The result of the network model is deployed in Hau Giang province, a province in Mekong Delta. Based on the experiment results, we can deploy the OBSNET in the Mekong Delta region.

The experiment results show the effects of OBSNET based on honeyComb structure. Using this method not only helps to optimize the light trap position for BPH surveillance network but also saves the cost in actual deployment. Actual data is used to validate the correctness of the OBSNET.

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