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METHODOLOGY FOR OPTIMIZING THE FUNCTIONING OF THE OPTOELECTRONIC SURVEILLANCE SYSTEM

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ABSTRACT

Context. Radar, thermal imaging, and video surveillance means are actively used in the protection of the state border. Together with the appropriate communication equipment, they allow to create optoelectronic surveillance systems, which are the basis for the intellectualization of border protection. The effectiveness of such systems is significantly affected by the peculiarities of their functional and structural design. A rational structural design, even in difficult physical and geographical conditions, allows for a high level of surveillance efficiency. However, the functional component also has a significant impact on improving the system efficiency. In many cases, the functioning of the elements of the optoelectronic surveillance system occurs under conditions of power supply restrictions. Such limitations determine the need for a rational choice of modes of use of certain types of surveillance equipment at certain time intervals in order to ensure effective surveillance, taking into account the time of day and weather conditions. The imperfection of the scientific and methodological apparatus for optimizing the functioning of optoelectronic surveillance systems determines the relevance of this study.

Objective. The aim of the work is to develop a methodology for optimizing the optoelectronic surveillance system functioning by rationally selecting the modes of operation of different types of surveillance equipment in certain time intervals, taking into account the time of day and weather conditions in which they are used.

Methods. The paper sets and investigates the two-criteria problem of choosing the modes of operation of different types of observation equipment of an optoelectronic surveillance system at separate time intervals, taking into account the time of day and weather conditions in which they are used, which ensures maximizing the efficiency of the optoelectronic surveillance system while minimizing the power consumed by active types of surveillance equipment in the presence of boundary restrictions on the efficiency and power consumed by the system.

The proposed indicator for assessing the effectiveness of the system allows us to assess the level of impossibility of uncontrolled crossing of the perimeter of the protected area by an intruder. The peculiarity of this methodology is the possibility of ensuring a significant reduction in the level of energy consumption by the system components due to a slight decrease in the efficiency of monitoring.

Results. The paper proposes an alternative approach to assessing the effectiveness of the optoelectronic surveillance system, the idea of which is that instead of assessing the effectiveness of surveillance over the entire sector of the controlled area of the border, the effectiveness of control is assessed only along the perimeter of this area. This approach significantly reduces the computational complexity of the problem of finding the value of efficiency which further simplifies the solution of problems of structural optimization of surveillance systems. A software and algorithmic implementation of the methodology for optimizing the functioning of an optoelectronic surveillance system is proposed. Using the developed software, a rational choice of modes of operation of certain types of surveillance equipment at certain time intervals was carried out taking into account the time of day and weather conditions.

Conclusions. The use of the proposed methodology makes it possible to optimize the modes of operation of the optoelectronic surveillance system, taking into account the limiting factors in terms of efficiency and power consumption when using the same types of surveillance equipment on all towers of the system. A possible direction for improving the methodology is its adaptation to cases where different types of surveillance equipment are used on different towers of the system.

KEYWORDS: optoelectronic surveillance system, methodology, optimization, efficiency, power consumption, algorithm.

ABBREVIATIONS

SBGSU – State Border Guard Service of Ukraine;

OSS – optoelectronic surveillance system.

NOMENCLATURE

Y – set of weather conditions;

y_i (i=[1,u]) – elements of the set of weather conditions;

$T_∂$ – time of day;

T_c,T_m – light, dark periods of the day;

T – period of time during which the functioning of the OSS is studied;

t_i (i=[0,s]) – start times of the studied elementary discrete time ranges in the time interval during which the functioning of the OSS is studied;

t_0 – moment of the beginning of the first elementary discrete time range in the interval T (the moment of the beginning of the period T);

t_s – start time of the last elementary discrete time range in the interval T;

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$n_{j,ti}$ (j=[1,k]) – number of surveillance devices of the j-th type operating in the OSS during an elementary discrete time range starting at t_i time;

$P_{j,ti}$ (j=[1,k]) – power consumption of electricity by the j-th type of observation means during an elementary discrete time range starting at t_i time, characterized by specific y_i weather conditions (for example, from a weather forecast service) and the period of day;

P_T – power of electricity consumed by active types of OSS monitoring devices during the T studied period T;

P_0 – maximum permissible power limit of the consumed electricity by active types of OSS monitoring equipment during the T studied period;

E_{j,t_i} – effectiveness of the j-th type of observation means during an elementary discrete time range starting at t_i time, characterized by specific weather conditions y_i (for example, from a weather forecast service) and the period of day;

E_T – effectiveness of the OSS during the T studied period in detecting the fact of violation of the border section perimeter;

E_0 – minimum permissible limit of OSS efficiency during the T studied period;

$pv_k(p_{ij}, y_i, x, y)$ – probability of detecting a target by a surveillance device of the k-th type located at p_{ij} point, in an elementary section of the studied control area with a centre at point (x, y) and under weather conditions y_i.

INTRODUCTION

Reliable protection of Ukrainian borders is an absolute guarantee of their inviolability in peacetime. In today's environment, effective protection is impossible without proper engineering equipment and border arrangements. This equipment, in particular, includes the latest technical surveillance equipment, such as thermal imaging cameras, modern radar stations and video cameras, as well as modern communication means. The effectiveness of a surveillance system built with such equipment depends heavily on the perfection of its structural and functional organization, as well as the compliance of the chosen mode of use of the equipment with the weather and other conditions in which the surveillance is carried out. When solving the problems of structural optimization of the surveillance system, the use of the effectiveness indicator, which is focused on assessing the functioning of the entire sector of the border area under study is not always rational. In most cases for the effective organization of border protection, the urgent task is to ensure the most effective monitoring of the perimeter of the sector of the studied area, and in case of its violation, the sector of the entire area limited by the specified perimeter. Therefore, it is important to clarify an objective indicator of the effectiveness of monitoring the perimeter of the border area.

In some cases, the operation of OSS must be carried out with autonomous power supply of equipment through the use of renewable energy sources. All of this makes it important to optimize the use of a complex of surveillance equipment while maximizing their efficiency and minimizing their energy consumption.

It is assumed that under fixed observation conditions, one of the monitoring devices can provide an efficiency close to the total efficiency provided by the simultaneous operation of all types of devices. In this case, a significant improvement in the energy efficiency of the system can be achieved by slightly reducing the efficiency of monitoring when operating only one of the most efficient means of monitoring in specific conditions.

The object of research is the functioning of the optoelectronic surveillance system.

The subject of research are the methods of optimizing the functioning of the optoelectronic surveillance system.

The purpose of this work is to develop a methodology for optimizing the functioning of the optoelectronic surveillance system by rationally selecting the modes of operation of different types of surveillance equipment at certain time intervals taking into account the time of day and weather conditions in which they are used. This methodology provides the establishment of an indicator of the effectiveness of the OSS in detecting an intruder at the border of the area where control is to be ensured.

1 PROBLEM STATEMENT

Suppose that OSS consists of n observation towers, the location of which is stationary and optimized for the problem under study [1]. Each tower has k types of surveillance equipment. There are quite a few possible types of surveillance equipment. Typically, optical, optoelectronic, thermal imaging and radar stations are used at OSS. The effectiveness of surveillance equipment varies depending on the conditions of use. The conditions of use include weather conditions and time of day.

Depending on the time of year, the duration of the light T_c and dark T_m periods of the day T_∂ are different and variable.

Certain types of surveillance equipment on the towers can operate independently of each other and regardless of what types of equipment are operating on other towers. For the purposes of this study, we will assume that during an elementary discrete time range starting at t_i time, the same type of surveillance equipment can operate on all towers.

Given that the E_T indicator is for the T period, which can be either partially occurred or fully occurred in the future, to find E_T, you can use the values y_i, which are determined from the weather forecast service for each elementary discrete time range starting at t_i time.

The task is to determine for T period, taking into account the set of y_i values, which are determined from the weather forecast service and are characteristic of T period, the types of observation devices on the OSS towers that will provide

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$$E_T \to \max, \tag{1}$$

$$P_T \to \min. \tag{2}$$

with restrictions

$$E_T \geq E_0, \tag{3}$$

$$P_T \leq P_0. \tag{4}$$

In the optimization problem (1)–(4)

$$E_T = \sum_{\substack{t_i = t_0,\\ j}}^{t_s} n_{j,t_i} E_{j,t_i}, \tag{5}$$

$$P_T = \sum_{\substack{t_i = t_0,\\ j}}^{t_s} n_{j,t_i} P_{j,t_i}. \tag{6}$$

In the right-hand sides of expressions (5), (6), the summation is performed by the values that determine the active surveillance means for each elementary discrete time range starting at t_i time.

The solution of problems (1)–(6) makes it possible to plan the operating modes of the OSS monitoring elements for the T period, as well as (if necessary) to adjust these modes if the time T interval is sufficiently long, or the data from the weather forecast service is not accurate enough, or is accurate enough only for small periods of time.

2 LITERATURE REVIEW

A significant number of scientific papers are devoted to the study of improving the functioning of surveillance systems. A general overview of surveillance systems is given in [2]. This study examines the features of the construction of surveillance systems and the basic procedures for processing information in them. Also, [2] identifies trends in the development of surveillance systems and relevant areas for further research in this area.

Paper [3] discusses the improvement of air target signal detection in complex surveillance systems.

Many researchers focus on the issues of efficient information processing in surveillance systems to automate object detection. For example, work [4] considers the use of neural networks with deep-learning algorithms for this purpose. Similarly to the previous study, the issues of image classification using neural networks are reflected in [5]. An interesting and promising area of development of modern surveillance systems is the acquisition and processing of images from unmanned aerial vehicles [6]. Methods of image comparison with mask construction are discussed in [7].

In the construction of surveillance systems, especially when using surveillance equipment with limited communication capabilities, attention is paid to optimizing the transmission of video streams. Thus, in [8], a model for classifying informative image segments is proposed, on the basis of which information redundancies in aerial photographs are eliminated.

Some studies in the field of surveillance systems [9–10] are devoted to the integration of images in different parts of the spectral range. Thus, [9] proposes to improve the methods of forming integrated multispectral images by taking into account their local features. Study [10] identifies possible ways to increase the information content of images based on the determination of the operating modes of multispectral optical channels.

A number of works [1, 11–12] address the issues of structural and functional optimization of OSS used in border protection. However, these studies use an efficiency indicator that reflects the ability to conduct surveillance over the entire area to be controlled. At the same time, in many partial variants of the use of surveillance systems, it is sufficient to reliably control only the perimeter of the site. And this requires an appropriate adjustment of the performance indicator.

Along with the structural and functional optimization of surveillance systems [12], it is also advisable to rationally choose the mode of operation of surveillance means in accordance with weather and other conditions in order to reduce energy consumption and ensure sufficiently high efficiency. All this determines the relevance of further relevant research.

3 MATERIALS AND METHODS

An important component of the OSS, which significantly affects the overall efficiency of its use, is a complex of towers with installed surveillance equipment, the functioning of which is based on the use of electromagnetic radiation in different frequency range (Figure 1).

Depending on the conditions in which the surveillance is conducted, the surveillance equipment of the OSS provides different efficiency. Each of the devices consumes a certain amount of power from the power source. In some cases, when the power supply is autonomous, its resource is limited. This prompts the search for ways to optimize power consumption.

Under certain weather conditions, the effectiveness of surveillance using a particular type of sensor can be significantly better than that provided by other types of sensors. In this case, from the point of view of minimizing energy consumption, it is inappropriate to use all available types of surveillance equipment at the same time. It is assumed that due to the rational choice of the type of observation means for each elementary discrete time range starting at t_i time, corresponding to the weather and other conditions in which the observation is carried out, and possibly a slight decrease in efficiency, significant savings in electricity consumption can be

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achieved. Such savings can be extremely important in cases of using renewable energy sources (sun, wind, etc.).

For example, if three types of surveillance equipment are used on OSS towers, the option of using separate types of equipment on separate time ranges without taking into account the restrictions on the power consumption by them can be determined as follows. First of all, the effectiveness of the observation means of $j=1$, $j=2$, $j=3$ type on elementary discrete time points starting at t_i time moments during the studied period T is determined (see Fig. 2), and then the option of using observation means (see Table 1) is established as a choice of the type of means $j=1$, $j=2$, $j=3$, for each elementary discrete time band starting at t_i time points which is characterized by maximum efficiency.

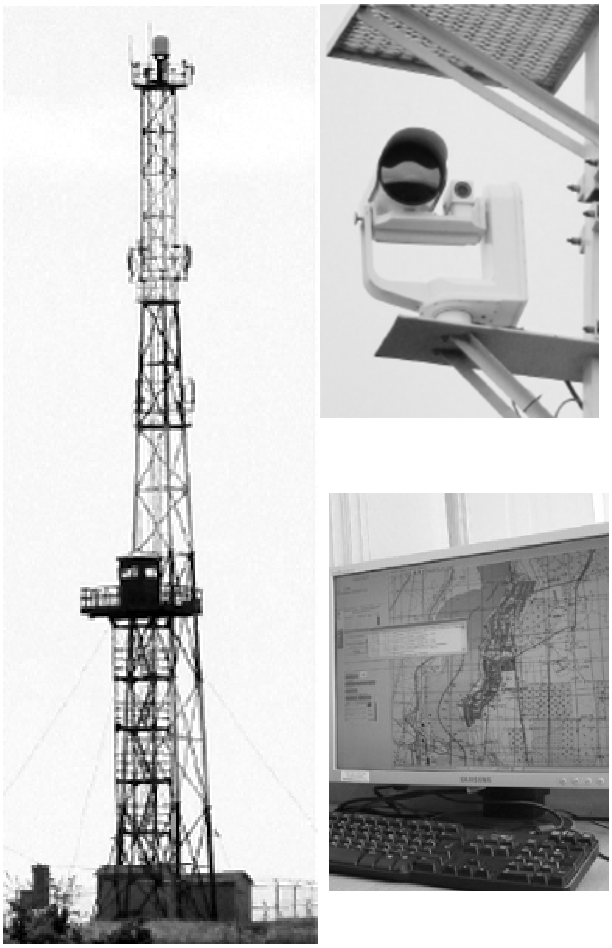

Figure 1 – Example of OSS tower and devices

It should be noted that if it is necessary to take into account restrictions on electricity consumption, the option of using surveillance equipment may differ from that given in Table 1. For example, if the power consumption of the $j=2$ device is significantly higher than the power consumption for the $j=3$ device, then the option of using surveillance equipment may be as given in Table 2.

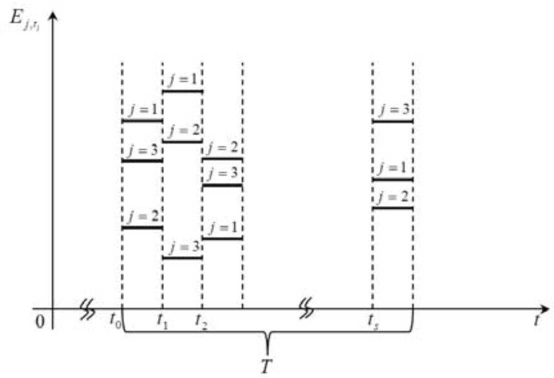

Figure 2 – A possible variant of realization of efficiency by means of observations of $j=1$, $j=2$, $j=3$ type on elementary discrete time ranges with a start at t_i time during the studied period T

Table 1

The research period	T				
The beginning of the studied elementary discrete time ranges	t_0	t_1	t_2	…	t_s
The j type of observation device that is appropriate for use in the elementary discrete time range under study	1	1	2	…	3

Table 2

The research period	T				
The beginning of the studied elementary discrete time ranges	t_0	t_1	t_2	…	t_s
The j type of observation device that is appropriate for use in the elementary discrete time range under study	1	1	3	…	3

At the same time, the decision to use a particular type of surveillance device is formed on the basis of solving the optimization problem (1)–(6). That is why the task set out in this paper becomes relevant.

The analysis of expressions (5), (6) allows us to conclude that the solution of the optimization problem (1)–(6) directly depends on the type of E_{j,t_i} function .

The task of determination this type of function was studied in [1, 11–12]. In these works, an indicator similar to E_{j,t_i}, was determined on the basis of a probabilistic approach, according to which, for each observation means, the dependence of the probability of detecting an object on the distance to it was experimentally determinated, in accordance with the observation conditions. This approach made it possible to take into account both deterministic and stochastic factors that affect the detection of objects in specific observation conditions. In these works, such an indicator had the following form:

$$E_S = \frac{\sum_{(x,y)\in S_m} (1-\prod_{i,j}(1-pv_k(p_{ij}, y_t, x, y)))}{nSm}. \quad (7)$$

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This efficiency indicator provided the possibility of averaging the probability of detecting objects over all (x,y) discrete elements of S_m observation band area (Figure 3).

The E_s calculation takes into account the possible fertilizing effect of the terrain. This is ensured by using the capabilities of modern information technologies.

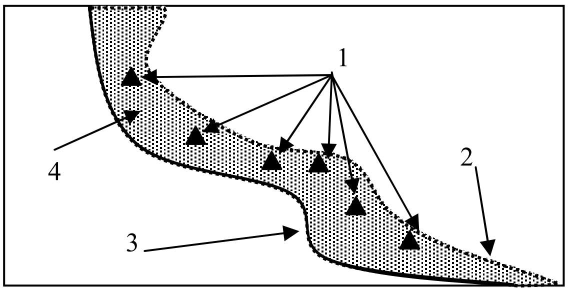

Figure 3 – Diagram of the layout of OSS elements:
1 – observation towers, 2 – perimeter of observation,
3 – border line, 4 – observation lane

If the element of (x,y) location is not visible (i.e., if the (x,y) element belongs to the invisible zone), the corresponding value of $pv_k(p_{ij}, y_i, x, y)$ is 0. If this element is visible, then the following formula is used to calculate $pv_k(p_{ij}, y_i, x, y)$

$$pv_k(p_{ij}, y_t, x, y) = \begin{cases} P_1(R(p_{i,j}, x, y), k, y_i), (x, y) \notin T_{p_{ij}}, \\ 0, (x, y) \in T_{p_{ij}}, \end{cases} \quad (8)$$

where

$$P_1(R, k, y_i) = 1 - \frac{1}{\sigma_R(k, y_i)\sqrt{2\pi}} \int_{R_{\min}}^{R} e^{-\frac{(R - m_R(k, y_i))^2}{2\sigma_R^2(k, y_i)}} dR. \quad (9)$$

In expression (7), nSm this is the number of discrete elements (x,y) of S_m.observation band area.

Expression (8) implements a probabilistic description of the effectiveness of detecting an object by the k-th observation means depending on the distance R to it. The R distance is determined by the coordinates of the p_{ij} observation point (corresponding to the OSS tower where the equipment is installed) and the coordinates (x,y) of the center of the elementary area under observation According to the observation conditions and the type of observation means, the parameters of the distribution law (the mean and variance of the random variable R) are selected in (9). These parameters are set experimentally on the basis of statistical processing of tests of the corresponding observation means in different conditions. When applying formula (8), geoprocessing is used, which consists in determining the correspondence of the area (x,y) to the set of invisibility zones from the tower located at p_{ij} point.

However, such a determination of the efficiency indicator (7) requires finding the visibility of each of its discrete elements (x,y). This task for S_m large areas even when using optimized algorithms for determining visibility has a great computational complexity.

Taking into account the fact that in many cases it is not necessary to observe the whole area of the observation strip when controlling the border section, and to detect objects it is enough to observe only the perimeter of the section, then taking into account the probabilistic approach implemented in dependencies (7)–(9), the efficiency indicator can be represented as

$$E_{j,t_i} = \frac{\sum_{(x,y)\in l_m} (1 - \prod_{i,j} (1 - pv_k(p_{ij}, y_i, x, y)))}{nl_m}. \quad (10)$$

In contrast to (7), in (10), the summation and calculation of $pv_k(p_{ij}, y_i, x, y)$ with the determination of visibility (x, y) is not performed over the entire area of the S_m observation sector, but only along l_m perimeter.

Thus, this approach defines an original methodology for optimizing the functioning of the optoelectronic surveillance system by rationally selecting the modes of operation of different types of surveillance equipment at certain time intervals taking into account the time of day and weather conditions in which they are used.

In the above methodology E_{j,t_i} the quantities may have a complex characteristic (not necessarily the one shown in Fig. 2). In this case the application of the approach described in Fig. 2 and Tables 2–3 is not obvious. Consequently, solving problems (1)–(6) can be significantly complicated even though the computational complexity of the problem is reduced by conducting a study on the border of the perimeter of the observation sector S_m.

In order to specify the proposed methodology, we will conduct additional analysis.

The time of day has a significant impact on the effectiveness of surveillance equipment. For example, if we compare two types of surveillance cameras operating in the visible and far infrared ranges (thermal imaging cameras), then during daylight hours, an optical range camera will be preferable for detecting objects, as it provides significantly higher resolution. At the same time, the simultaneous use of these cameras will lead to unnecessary energy consumption. However, the situation will change dramatically with the onset of darkness. This can be estimated from the graph shown in Fig. 4.

During daylight hours, the probability of detecting an object using an optical range camera under favorable weather conditions is quite high (Figure 4 – solid line). However, this probability decreases significantly when the light level decreases. For a thermal imaging camera (Figure 4 – dotted line), the situation is significantly different. At night, a thermal imager can clearly distinguish objects even in the dark, making it an indispensable tool for nighttime surveillance. However, during the day, when the environment is warm, the thermal imager may have more difficulty in detecting objects because the temperature difference between the objects and the environment is smaller.

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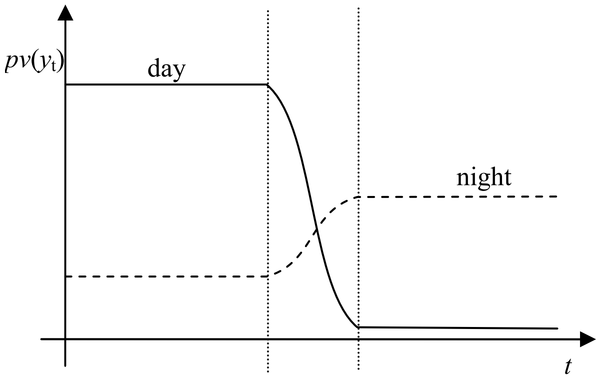

Figure 4 – Dependence of detection probability at a fixed distance for two different types of surveillance equipment on time

Weather conditions Y also have a significant impact on the effectiveness of surveillance equipment. It should be noted that the dependence of efficiency on time for different types of surveillance equipment, taking into account possible changes in the conditions of observation, can be complex (Figure 5). This is influenced by a combination of different factors.

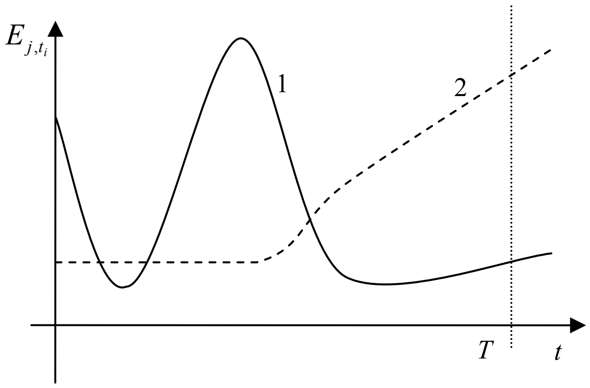

Figure 5 – Possible dependencies of the efficiency indicator (10) for two different types of surveillance equipment on time taking into account the conditions of observation

During the studied T time interval, within which one of the types of surveillance means is chosen, the efficiency for different surveillance means can change dramatically. Thus, at the beginning of the studied interval (Figure 5 – solid line), the best efficiency is provided by the 1-st surveillance means. However, this effectiveness for the 1-st means decreases sharply over time, and the use of the 2-nd means becomes preferable. However, after a short period of time, the 1-st means again provides greater efficiency. All of this makes it difficult to choose the surveillance tools for individual discrete time periods.For a rational choice of an observation tool, one can use a comparison of the mathematical expectations of the E_{j,t_i} value over the T time interval. However, it should be noted that the minimum and maximum efficiency are also important. Given that the minimum, maximum, and average efficiencies for individual instruments are not always such that they unambiguously determine the choice of an instrument, it is necessary to determine a selection criterion.

The analysis allows us to assume that it is advisable to use the mathematical apparatus of fuzzy values for the rational choice of an active surveillance means. The effectiveness of each type of surveillance means in the studied interval can be determined by the E_T,fuzzy value which is described by a triangular function that takes into account the minimum, average and maximum values of the corresponding effectiveness. In this case, the membership function for fuzzy efficiency will be given as

$$\mu(E_T) = \begin{cases} 0, E_T < \min E_{j,t_i}, \\ 1, E_T = M[E_{j,t_i}], \\ 0, E_T > \max E_{j,t_i}, \end{cases} \quad (11)$$

where M[] is the operator of mathematical expectation.

The concept of fuzzy maximum is used to compare the fuzzy efficiencies (11) of different types of surveillance means.

Thus, the concretization of the proposed methodology for optimizing the functioning of the optoelectronic surveillance system through the rational choice of the mode of using different types of surveillance equipment in accordance with weather and other conditions concerns the mechanisms for determining E_{j,t_i} values.

4 EXPERIMENTS

In order to automate the calculation of the value (10), a software application was developed (Figure 6).

The application implements geoprocessing to determine the areas of the sectors visible from the observation towers. Observation conditions including weather conditions are set using the appropriate interface elements and, accordingly, the program selects the parameters of the probabilistic description of the operation of the observation means. In addition to calculating a predefined indicator of the effectiveness of monitoring the area (7), the application implements the calculation of the effectiveness of controlling the perimeter of a certain area (10). For convenience, the storage and reading of the locations of observation towers, which can be edited, is implemented.

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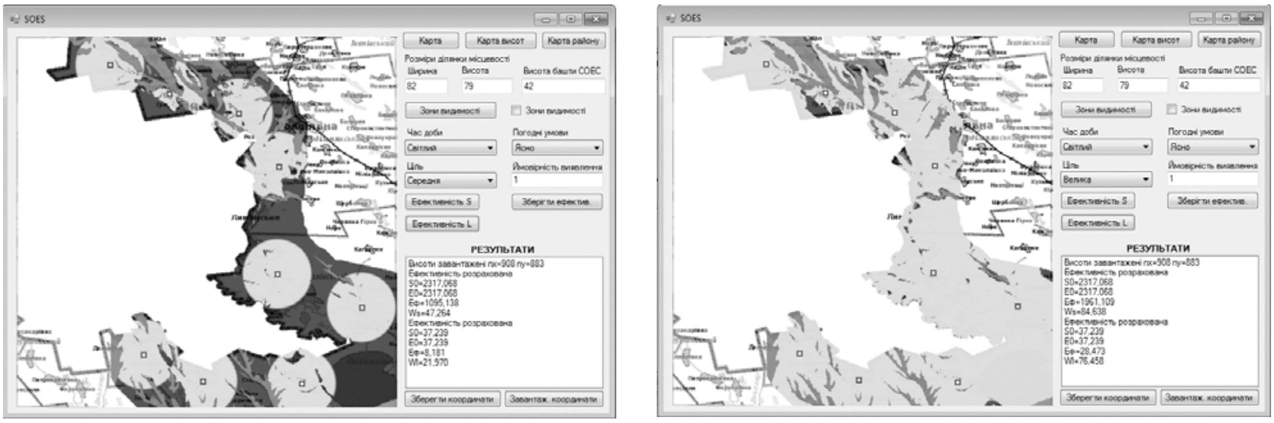

a b

Figure 6 – An application for automating efficiency finding (10)

5 RESULTS

Figure 6 shows some examples of the results of calculating the indicators of observation efficiency by area (7) and by perimeter (10).

When calculating the corresponding indicators, the window displays the total area of the areas for which $pv_k(p_{ij}, y_i, x, y)$ is calculated. These calculations constitute the main computational complexity in solving the problem. From the above examples of application use, it can be concluded that the computational complexity is reduced by more than 60 times.

An interesting fact is that in all variants, the absolute values of the efficiency indicator (10) are lower than the value of (7). On the one hand, this is explained by the fact that the task of structural optimization of the OSS – the placement of observation towers was carried out with the maximization of (7). However, the main reason is that the physical meaning of indicators (7) and (10) is to average the values of the probability of detecting an object over all elementary areas that make up the study area (in the case of (7)) or perimeter (for indicator (10)). At the same time, a significant part of the area is located relatively close to the observation towers, where a high probability of detecting targets is ensured. Therefore, the average value can be quite close to 1. In the case of performance indicator (10), most areas of the perimeter of the surveillance strip are located at a considerable distance from the towers, and therefore the averaged values are significantly lower.

However, within the framework of using each of the efficiency indicators, it is possible to compare different means of surveillance in different conditions and choose the most appropriate mode of operation of the system in accordance with these conditions.

To choose such a mode, a technique is proposed that, using the mathematical apparatus of fuzzy values, ensures the determination of the observation device that provides the best observation efficiency over T time period.

6 DISCUSSION

The methodology for optimizing the functioning of the optoelectronic surveillance system developed in this paper is unique due to the use of two optimization criteria, unlike the existing ones [1, 11–12]. The solution of a two-criteria optimization problem is not only of practical importance, but also of theoretical significance which consists in the development of the theory of computational processes. In the studied problem, a new indicator for assessing the effectiveness of the system's functioning is also used for the first time, which, unlike the existing ones allows assessing the level of impossibility of uncontrolled crossing of the perimeter of the protected area by an intruder.

The peculiarity of the studied problem, which somewhat idealizes the process of using the monitoring elements of OSS, is that the same type of monitoring equipment was chosen at all observation towers. The issue of establishing the dependence of observation effectiveness on the choice of different means on different towers under certain observation conditions (a generalized problem) is currently unexplored. However, the proposed approach to solving the problem studied in this paper can be applied as one of the stages of solving the generalized problem.

CONCLUSIONS

The problem of optimizing the functioning of the optoelectronic surveillance system in accordance with its formulation in this study can be considered solved.

The scientific novelty of the obtained results lies in a new approach to determining the efficiency of detecting objects in the observation sector by an optoelectronic surveillance system.

The paper sets and investigates a two-criteria problem of choosing the modes of operation of different types of surveillance equipment of an optoelectronic surveillance system at certain time intervals, taking into account the time of day and weather conditions in which they are used, which ensures maximizing the efficiency of the optoelectronic surveillance system while minimizing the power consumed by active types of surveillance

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equipment in the presence of boundary constraints on the efficiency and power consumed by the system.

The proposed indicator of the system's functioning efficiency allows us to assess the level of impossibility of uncontrolled crossing of the perimeter of the protected area by an intruder.

The practical significance of the obtained results lies in the programmatic implementation of the proposed mathematical apparatus for assessing the efficiency of OSSs functioning in different conditions under which observation is carried out.

Prospects for further research include solving the problem under study by choosing different types of surveillance equipment or their combinations, on different towers as well as testing the hypothesis that this may achieve better results in some cases.

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МЕТОДИКА ОПТИМІЗАЦІЇ ФУНКЦІОНУВАННЯ СИСТЕМИ ОПТИКО-ЕЛЕКТРОННОГО СПОСТЕРЕЖЕННЯ

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АНОТАЦІЯ

Актуальність. При охороні державного кордону активно застосовуються радіолокаційні, тепловізійні та відео засоби спостереження. Разом з відповідним комунікаційним обладнанням вони дозволяють утворювати системи оптико-електронного спостереження, які є основою для інтелектуалізації охорони кордону. На ефективність використання таких систем суттєво впливають особливості їх функціональної і структурної побудови. Раціональна структурна побудова навіть у складних фізико-географічних умовах дозволяє забезпечувати високий рівень ефективності спостереження. Однак значний вплив на підвищення ефективності системи має і функціональна складова. Функціонування елементів системи оптико-електронного спостереження в багатьох випадках відбувається в умовах обмежень щодо використання електроживлення. Такі обмеження визначають необхідність раціонального вибору режимів використання окремих типів засобів спостереження на окремих часових інтервалах з метою забезпечення ефективного спостереження з урахуванням періоду доби та погодних умов. Недосконалість науково-методичного апарату оптимізації функціонування систем оптико-електронного спостереження визначає актуальність даного дослідження.

Мета. Метою роботи є розробка методики оптимізації функціонування системи оптико-електронного спостереження за рахунок раціонального вибору режимів функціонування різних типів засобів спостереження на окремих часових інтервалах з урахуванням періоду доби та погодних умов, в яких вони використовуються.

Метод. У роботі поставлена та досліджена двокритеріальна задача вибору режимів функціонування різних типів засобів спостереження системи оптико-електронного спостереження на окремих часових інтервалах з урахуванням періоду доби та погодних умов, в яких вони використовуються, що забезпечує максимізацію ефективності функціонування системи оптико-електронного спостереження при мінімізації потужності спожитої електроенергії активними типами засобів спостереження за наявності граничних обмежень щодо ефективності та потужності спожитої системою електроенергії.

Запропонований показник оцінки ефективності функціонування системи дозволяє оцінити рівень неможливості неконтрольованого перетину порушником периметру ділянки, що охороняється. Особливістю зазначеної методики є можливість забезпечення суттєвого зниження рівня енергоспоживання складовими системи за рахунок незначного зниження ефективності спостереження.

Результати. У роботі запропонований альтернативний підхід для оцінки ефективності функціонування системи оптико-електронного спостереження, ідея якого полягає в тому, що замість оцінювання ефективності спостереження по всій площі контрольованої області ділянки кордону, оцінюється ефективність контролю лише за периметром цієї області. Такий підхід суттєво зменшує обчислювальну складність задачі відшукання значення ефективності, що в подальшому спрощує вирішення задач структурної оптимізації систем спостереження. Запропоновано програмно-алгоритмічну реалізацію методики оптимізації функціонування системи оптико-електронного спостереження. З використанням розробленого програмного забезпечення проведено раціональний вибір режимів функціонування окремих типів засобів спостереження на окремих часових інтервалах з урахуванням періоду доби та погодних умов.

Висновки. Використання запропонованої методики дозволяє оптимізувати режими функціонування системи оптико-електронного спостереження з урахуванням обмежуючих факторів щодо ефективності та потужності енергоспоживання при застосуванні однакових типів засобів спостереження на всіх вежах системи. Можливим напрямом удосконалення методики є її адаптація до випадків застосування на різних вежах системи різних типів засобів спостереження.

КЛЮЧОВІ СЛОВА: система оптико-електронного спостереження, методика, оптимізація, ефективність, енергоспоживання, алгоритм.

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