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MULTI-CRITERIA PROBLEM OF THE ALARM SYSTEMS COST-FUNCTIONAL CHARACTERISTICS OPTIMIZATION

Summary. In present study the problem of an alarm systems optimization was presented and the stages of the multicriteria structured optimization method in cost-functional characteristics of the alarm system were also described. The method represents a combination of the proposed reflection and selection schemes in the genetic algorithm that solves the extreme combinatorics problem.

WIELOKRYTERIALNY PROBLEM OPTYMIZACJI CENOWO-FUNKCJONALNYCH CECH SYSTEMÓW ALARMOWYCH

Streszczenie. W proponowanym badaniu przedstawiono problem optymalizacji systemów alarmowych oraz zostały opisane etapy metody wielokryterialnej, strukturalnej, cenowo-funkcjonalnej optymalizacji systemu alarmowego. Metoda stanowi kombinację refleksji i planu wyboru algorytmu genetycznego, który rozwiązuje problem ekstremalnej kombinatoryki.

1. Introduction

To create an alarm system, an appropriate territory perimeter is divided into several parts, called zones. Every zone defines a set of threats that can be caused by an intruder. Different types of detectors are being used to monitor these threats according to their detection ranges (Fig. 1).

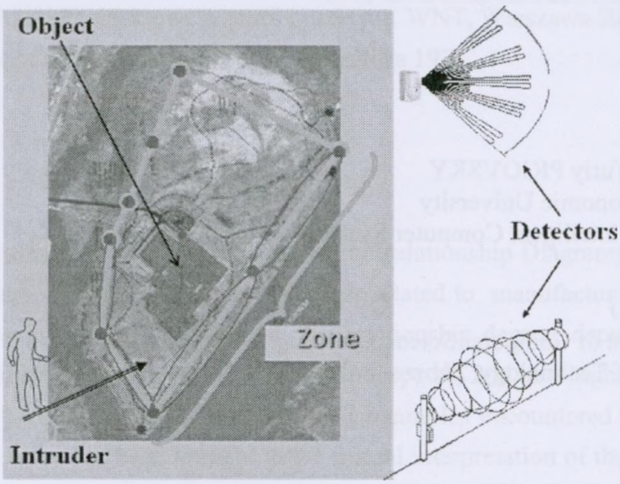

Fig. 1. Perimeter of the territory divided by zones
Rys. 1. Obwód terytorium podzielony na strefy

Usually, companies that install alarm systems use the template solutions that are not always suitable (not adapted to the specific perimeter of the territory) according to their functional characteristics. Therefore a presenting of the alarm system that provides a compromise between price and efficiency for a provided territory is an actual aim. The solution of this problem can be organized in two ways: (i) an optimal implementation of the alarm system components and (ii) an improvement of the components.

The first way consists of the creation methods that ensure the development of the entire alarm system with the required efficiency and minimal resource-demands.

The second way includes a development of the new alarm system component types that have better parameters than their predecessors - a challenging task, or modification of the existing components, which requires less effort.

1.1. Known solutions

It is suitable to name among the well-known solutions for an alarm system vulnerability assessment the following ones: ASSESS, ATLAS, SAVI, EASI, VISA, ADKBS, JCATS, TAM, FOF, SAFE, SNAP (USA), CLASP (England), "Vega-2" (Russia) [1–4]. However, they are unable to generate alternative structures of systems, they can only estimate the variants that are entered manually.

From computer-aided designs of the alarm systems we can single out CCTV CAD [5], but the area of its usage is limited only to video surveillance systems.

There is a single-criteria approach of Takehisa Kohda [6] among the means of functional and cost characteristics optimization of alarm systems. Pecuniary losses are taken into consideration as the criterion in this work. The criterion is estimated as the sum of such products as are: the penetration probability multiplied by penetration price and the false alarm penetration probability multiplied by its price. However, this approach ignores the character of the perimeter area.

The approach, proposed in this paper, takes the geometry of the area into consideration as a closed polygon and generates the structures of alarm systems for its protection by means of multicriteria optimization approach using (i) the false alarm probability, (ii) the undetection probability and (iii) resource-demands.

1.2. Probabilistic consequences of the zone penetration

The intruder may not be detected by an alarm system only in two cases: when the detector doesn't work due to a hardware fault or due to the specialized behavior of the intruder.

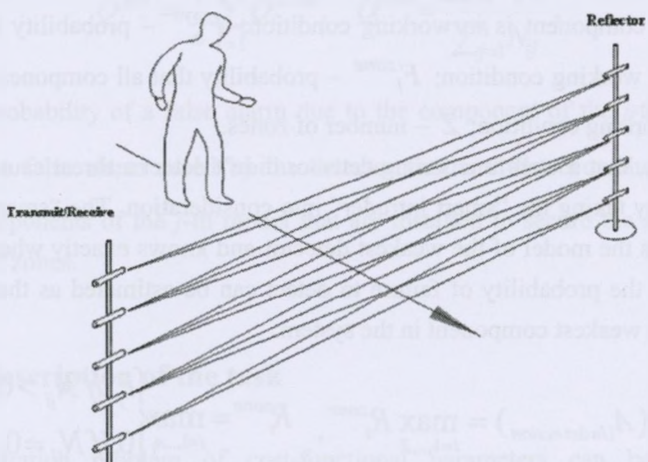

Fig. 2. Penetration of the secured zone by intruder
Rys. 2. Przejście intruza przez chronioną strefę

Probabilities of the mentioned above events can be described as: A_{Denial} – event „Intruder was not detected due to the condition, that at least one of detectors is disabled or damaged"; $A_{Undetection}$ – event „Intruder was not detected due to the condition, that at least one of working detectors didn't detect the defined threat", $A_{Detection}$ – event „The intruder was detected".

The probability of the intruder's undetection by alarm system $R^{sys} = 1 - P(A_{Detection})$ can be estimated as:

$$R^{sys} = P(A_{Denial}) + P(A_{Undetection}), \tag{1}$$

where $P(A_{Denial}), P(A_{Undetection})$ – probabilities of the events A_{denial} and $A_{Undetection}$, $P(A_{Denial}) << P(A_{Undetection})$.

The probability of hardware damage of the alarm system can be estimated using Druzhynin's [7] approach that means the following implies as a probability of sequential system functioning:

$$P(A_{Denial}) = 1 - F^{sys}, \quad F^{sys} = \prod_{i=1}^{Z} F_i^{zone}, \quad F_i^{zone} = \prod_{j=1}^{n_i} (p_j)^{N_{ij}}, \tag{2}$$

where n_i – number of component models, that can be used to secure the i-th zone; N_{ij} – amount of the j-th model components, that are used to secure i-th zone; p_j – probability that the j-th model of component is in working condition; F^{sys} – probability that all system components are in working condition; F_i^{zone} – probability that all components securing the i-th zone, are in working condition; Z – number of zones.

The probability, that a well-functioning detector didn't detect a threat caused by intruder, can be estimated by taking the "smart intruder" into consideration. The "smart intruder" is a person, who knows the model of the weakest detector and knows exactly where it is situated in the system. So, the probability of failure to detect can be estimated as the probability of undetection for the weakest component in the system:

$$P(A_{Undetection}) = \max_{i=1,\dots,Z} R_i^{zone}, \quad R_i^{zone} = \max_{j=1,\dots n_i} \begin{cases} r_j, if N_{ij} > 0, \\ 0, if N_{ij} = 0, \end{cases} \tag{3}$$

where r_j – value of undetection probability by the j-th model of components considering it is being in good condition (not damaged); n_i – number of component models, that can be used to secure the i-th zone; N_{ij} – amount of the j-th model components, that are used to secure i-th zone; R_i^{zone} – probability of threat undetection by well-functioning detectors in the i-th zone.

The purchase and setting up cost of the alarm system is calculated as a sum of the following prices:

$$C^{sys} = \sum_{i=1}^{Z} C_i^{zone}, \quad C_i^{zone} = \sum_{j=1}^{n_i} c_j N_{ij}, \tag{4}$$

where c_j – purchase cost, installation and warranty service for the detector of the j-th model; n_i – amount of component models that can be used to secure the i-th zone.

1.3. General probability of false alarm

A false alarm is not so vital as the failure to detect an intruder and therefore, it is suitable to use not so strict criteria as maximum probability value (3), but a weaker average value. This choice has an advantage of better variability and size of the resulting Pareto-set alarm systems structures. Moreover, the average probability value is a commonly used criterion, for instance, in the reliability theory [7], where it is proven to be effective in most of the problems. The average probability of false alarm is estimated as

$$Q^{sys} = \frac{1}{Z}\sum_{i=1}^{Z} Q_i^{zone}, \quad Q_i^{zone} = \frac{\sum_{j=1}^{n_i} N_{ij} q_j}{\sum_{j=1}^{n_i} N_{ij}}, \tag{5}$$

where q_j – probability of a false alarm due to the component of the j-th model; Q_i^{zone} – probability of a false alarm cased by the detector that is situated on the i-th zone; N_{ij} – number of components of the j-th model that are installed to secure the i-th zone; Z – the total amount of zones.

2. Formal description of the task

An optimization problem of cost-functional parameters can be presented as a multiobjective target function with limitations. Using provided cost-functional parameters (1)-(5), the optimization problem can be ensured as a multiobjective target-function:

$$\left(Q_{sys}(\vec{N}), R_{sys}(\vec{N}), C_{sys}(\vec{N})\right) \xrightarrow{\vec{N}} \min, \tag{6}$$

filling the limitations on zone perimeter coverage by detectors detection ranges, where each line means a separate zone that is covered by detection ranges of a certain number of components:

$$\begin{cases} L_1 N_{1,1} + L_2 N_{1,2} + \dots + L_n N_{1,n} \geq S_1, \\ L_1 N_{2,1} + L_2 N_{2,2} + \dots + L_n N_{2,n} \geq S_2, \\ \quad \vdots \qquad\qquad \vdots \qquad\qquad \vdots \\ L_1 N_{Z,1} + L_2 N_{Z,2} + \dots + L_n N_{Z,n} \geq S_Z, \end{cases} \tag{7}$$

where $\bar{N} = (N_{1,1}, N_{1,2} \dots N_{Z,n})$, $N_{i,j}$ - amount of components of the j-th model on the i-th security zone; n – amount of component models; Z – the total amount of zones; S_i – length of the i-th zone; L_j – detection range of the component of the j-th model.

2.1. Problem characteristics

The problem (6)–(7) has the following properties:

- multiobjective, i.e. impossible to be solved using regular single-criteria methods without aggregation;
- multimodal – have local extremum, it means that alarm systems may have large amount of solutions, that are similar in their target value but extremely different in their structure;
- nonlinear, (2) and (3) are nonlinear and discrete value functions, i.e. each new component leads to a complex change in the system criteria (6);
- discrete, i.e. detection ranges do not always evenly divide the perimeter of the territory.

These properties refuse the usage of ordinary gradient methods. Therefore methods of combinatorical optimization were analyzed: full and limited search, random search, methods of branches and limitations, evolutionary methods.

2.2. Homogeneous Morphological Table

The development of the methods that solve combinatory problems, involves their representation in a form of a morphological table. This table contains components of the alarm system and variants of their usage.

The method is based on a sequential selection of the implementation (column) for every component type (row) that produce a variant of the alarm system. Table 1 illustrates a morphological table for several types of components and models that implement them.

Total amount of alternatives - k, presented by the morphological table, is estimated as

$$k = \prod_{i=1}^{m} n_i; \qquad O\left(\prod_{i=1}^{m} n_i\right) = \exp(m). \tag{8}$$

where n_i - is the size of the R_i set; m – the amount of component types.

Table 1

Homogeneous morphological table

Type of the component	Component models			
Detector	FMW-3	Linar	. . .	Barrier-300
Cable	CV-K 402	...	CV-K 404	-
Alarm Panel	CA-10	....	Integra	-
LCD Keyboard	INT-KLCDS-BL	Pyronix MX-ICON	-	-
Siren	SP-4006 R	SOW-300 R	SOW-100	-

According to (8) the number of alarm systems depends on the number of components exponentially; therefore it is impossible to process the full morphological table in a short time, when there is a large amount of components. Also, this approach doesn't take the length of zones and limitation on components usage into consideration. It leads to cost increase and detection probability reduction of the resulting alarm security systems.

2.3. Heterogeneous morphological table

The alternative to homogeneous morphological table is a heterogeneous one, where detectors covering different ranges of territory are used to produce variants of security for every zone. It allows to take the length of zones and limitations of the components usage into consideration (see Table 2). This approach will eliminate the redundant costs of alarm systems and will increase the probability of the intruder detection.

The number of alarm system variants, with zones of $S_1, S_1, ..., S_Z$ units in length can be estimated using

$$k \approx c^{\lceil S_1/L \rceil} c^{\lceil S_2/L \rceil} ... c^{\lceil S_Z/L \rceil}, \tag{9}$$

where L – minimal detection range of the detectors, S_j – length of j-th zone, c – number of binomial permutations of detectors, which fulfill L units of territory's perimeter.

According to (9) - the number of alarm system variants described by the heterogeneous morphological table depends exponentially not only on the number of detectors types, but on the number of zones and their length, as well.

Table 2

Heterogeneous morphological table

Zones	Variants of security zones (realization of detector combinations)			
1	variant 1	variant 2	...	variant 17
2	variant 1	variant 2	...	variant 94
3	variant 1	variant 2	...	variant 56
4	variant 1	variant 2	...	variant 49
Component Type	Component realizations			
Cable	CV-K 402	...	CV-K 404	-
Central Panel	CA-10	....	Integra 64	-
LCD Keyboard	INT-KLCDS-BL	Pyronix MX-ICON	....	INT-KLCD-GR
Siren	SP-4006 R	SOW-300 R	SOW-100	-

2.3.1. Variants of a single zone security

An example of a single zone security alternative variants is presented in Table III, where columns represent the detection ranges of each available component, and the rows define the number of an appropriate component for the current variant of security.

This problem is exhaustive for small and large perimeters and is impossible to be solved in a reasonable time. In addition, the convergence of exhaustive search, i.e. the number of Pareto variants generated per unit of time, is very small.

The Table 4 shows, that the duration of an exhaustive search increases dramatically with the addition of the detector models. Therefore, searching for the best method to solve this problem is a task of major importance.

Table 3

Alternative variants of the single zone security

No. of variant	200	100	75	75	50	50
1	1	0	0	0	0	0
2	0	2	0	0	0	0
3	0	1	1	0	0	0
4	0	1	0	1	0	0
5	0	1	0	0	1	0
6	0	1	0	0	0	1
7	0	0	2	0	0	0
* * *						
17	0	0	0	0	0	3

Table 4

Dependence of the iteration number and the duration of exhaustive search on the amount of available detector models

Amount of detectors	Number of exhaustive search iterations	Time of exhaustive search (for 2,0 Gz PC)
1	2	5
1	1	15 ms.
2	$\approx 3*10^6$	7 min.
3	$\approx 196*10^{12}$	4.6 days
4	$\approx 3*10^{12}$	6 years
5	$\approx 196*10^{12}$	433 years
6	$\approx 603*10^{12}$	1382 years

2.4. Random search method and genetic algorithm reflection that are encoding numbers into the structure of an alarm system

Random search and classic genetic algorithm allow the increasing size of the Pareto-optimal set of alarm systems that are designed in a certain period of time in comparison with exhaustive search algorithm. However, the most of the systems, designed by this approach, are redundant by cost, so it is necessary to modify the classical scheme of gene reflection into the structure of alarm system.

The easiest way of reflection consists of the alarm system structure encoding $\bar{X} = (N_{1,1}, N_{1,2}, ..., N_{z,n})$ as the sequence of $K = Z \times n$ integer numbers that describe the amount of components of every type:

$$\vec{g} = [g_1, g_2, ..., g_K],\ g_1, g_2, ..., g_K \geq 0,\ K = Z \times n, \tag{10}$$

where g_k – amount of the k-th model components units; Z – amount of perimeter zones;

n – number of detector variants: $n = \sum_{i=1}^{Z} M_i$; M_i – number of component models, which are applicable to secure the i-th zone.

Such approach is easy in implementation. However it produces systems with redundant cost, has small convergence and ignores the specifics of perimeter zones.

2.5. GA chromosome reflection method that codes residue numbers in an alarm security structure

The scheme limits the selection of component amount, preventing their redundant usage. The total length of the component detection ranges, which are already in use, limits the quantity of the rest of the components.

Such reflection procedure allowed eliminating the redundant costs of the systems; however, the part of Pareto-optimal solutions is still low. To fight against the latter, we propose to present this problem as a heterogeneous morphological table of Pareto-optimal zone cover variants.

In order to produce the table, the Goldberg algorithm was adopted, its functioning is described below. The adoption lays in the fact that it is used for selection of Pareto-optimal relationship of detectors on the set of all possible relations, in contrast to classical GA, which, in regular case, is used to estimate population fitness. Selection is carried out using the following recursive relation

$$\vec{g} = [g_{11}, g_{12}, \dots, g_{ij}, \dots, g_{ZM}],$$
$$0 \le g_{ik} \le \left\lceil \frac{S_i - \sum_{j=1}^{k-1} g_{ij} L_j}{L_k} \right\rceil, \tag{11}$$
$$k = 1, \dots, M_i, \quad i = 1, \dots, Z,$$

where g_{ij} is the residual number of detectors of the j-th model (a chromosome gene), which are installed on the i-th zone; S_i is the length of the i-th zone; L_k is the length of detector's effective detecting boundary, for detector of the k-th model, M_i is the number of detector models that are suitable to secure the i-th zone.

Let's take into consideration the main advantages and disadvantages of the method (11). The main disadvantage of the method is a small amount of solutions in final Pareto set. The final Pareto set is produced aggregating all the possible solutions of the problem. Of course, we can obtain such a set only for small alarm systems, but we can get an approximation of it for the large ones, as well.

The main advantages of the method are better convergence and absence of the redundant cost.

2.6. Adopted Goldberg's algorithm that produces a heterogeneous morphologic table of Pareto-optimal structures

In order to increase the size of Pareto-optimal set of alarm system structures, a new reflecting scheme was developed. The scheme reflects GA chromosomes to indexes of Pareto-optimal relationship of detectors filling the whole length of the zone. Its formal description is shown below.

Every gene specifies an index of Pareto-optimal variant for zone coverage in the morphological matrix, which was produced using Goldberg's algorithm.

Criteria $f_1 = Q_i^{zone}, f_2 = R_i^{zone}, f_3 = 1 - F_i^{zone}, f_4 = C_i^{zone}$, $f_j(\bar{N}^{(l)})$, $j = 1,2,3,4$ are target functions for minimum, structure $\bar{N}^{(1)}$ is strictly better than those of $\bar{N}^{(2)}$ if:

(i) the structure $\bar{N}^{(1)}$ is not worse than $\bar{N}^{(2)}$ for all the criteria, when $f_j(\bar{N}^{(1)}) \leq f_j(\bar{N}^{(2)})$ for all $j = 1,2,3,4$;

(ii) the structure $\bar{N}^{(1)}$ is strictly better in comparison with $\bar{N}^{(2)}$ in at least one criterion or $f_j(\bar{N}^{(1)}) < f_j(\bar{N}^{(2)})$ for at least one of $j = 1,2,3,4$.

Algorithm

Step 0: Start from $l = 1$

Step 1: For all $j \neq l$, compare if the structure $\bar{N}^{(j)}$ is strictly better than the structure $\bar{N}^{(l)}$ according to the described above conditions.

Step 2: If for any j, the structure $\bar{N}^{(j)}$ is strictly better than the structure $\bar{N}^{(l)}$, then mark the structure $\bar{N}^{(l)}$ as non Pareto-optimal.

Step 3: If all the solutions in the population were tested, i.e. the condition $l = N_{pop}$ is satisfied, then go to the step 4, else do $l = l + 1$ and go to the step 1, where N_{pop} is the amount of adequate structures, which were found at the first phase (number of chromosomes in the population of solutions).

Step 4: All the structures that were marked as non Pareto-optimal should be removed from the final population of solutions.

3. Proposed reflecting scheme of the optimal zone installation indices

The structure, covering all the zones of the secure object, can be presented as a chain of genes. Every gene is a Pareto-optimal variant of detectors installation, which fills a single zone of the territory

$$\bar{g} = [g_1, g_2, ..., g_i, ..., g_Z], \quad 1 \le g_i \le M_i, \quad i = 1, ..., Z, \tag{12}$$

where M_i is the number of Pareto-optimal variants, filling the i-th zone. The value of M_i and properties of every variant are obtained using the adopted Goldberg's algorithm.

Presentation of indices for Pareto-optimal installation of detectors as a gene chain is illustrated in the Fig. 3.

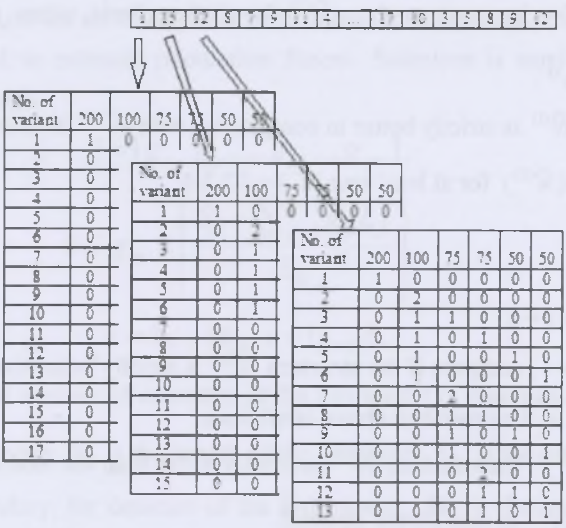

Fig. 3. Presentation of the chromosome as indices of Pareto-optimal installations using proposed method

Rys. 3. Prezentacja chromosomów, jako wskaźników Pareto-optymalnych instalacji, za pomocą proponowanej metody

The algorithm, which produces a set of possible detector installations that cover one zone, is used to decode the chromosome chain (see Fig. 3). The algorithm generates detector installations for one zone with the length of L units. The algorithm is based on the recursive function rec, which receives two arguments on its input (i – index of current detector model and the zone longitude). If the index of current detector model is outside the range of total number of detector models, the algorithm goes to its ending. The $sum(i)$ function is calculated as $\mathrm{sum(i)} = \sum_{k=i}^{M} \mathrm{rang}_k \cdot \mathrm{count}_k$.

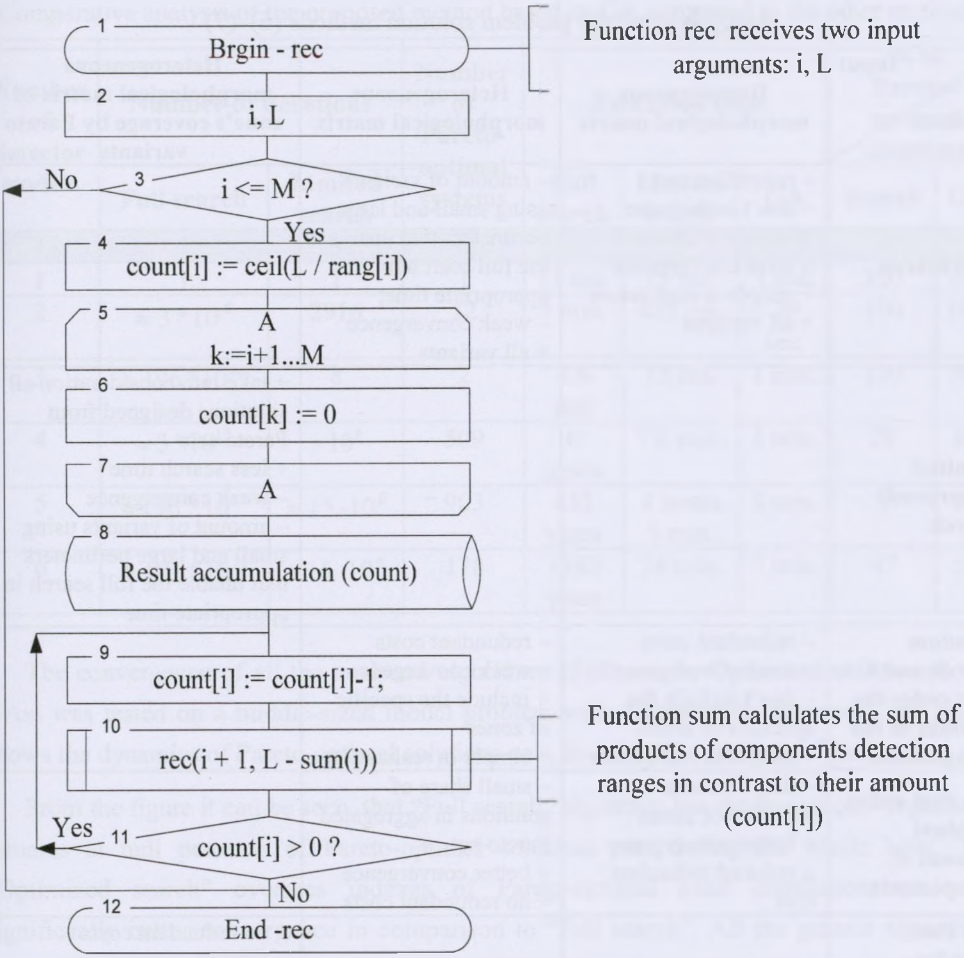

Fig. 4. Algorithm generating all possible detector installations for a single zone
Rys. 4. Algorytm generowania wszystkich możliwych instalacji z czujnikami dla jednej strefy

4. Stages of the task solution

After a thorough analysis of all the problem solution methods (6)–(7), we summarized their advantages and disadvantages in the table below.

Table 5

Analysis of all the problem solution methods (6)–(7)

Method \ Input	**Homogeneous morphological matrix**	**Heterogeneous morphological matrix**	**Heterogeneous morphological matrix of zone's coverage by Pareto variants**
Full search	– redundant costs – don't include the specifics of zones – weak convergence + simple in realization + all variants	– amount of variants using small and large perimeters that unable the full search in appropriate time; – weak convergence + all variants	–
Limited (improved) search	–	–	+ take into consideration all solutions designed from Pareto sets + less search time – weak convergence – amount of variants using small and large perimeters that unable the full search in appropriate time
Random search and GA that codes the amount of the components	– redundant costs – weak convergence – don't include the specifics of zones + simple in realization	– redundant costs – weak convergence + include the specific of zones + simple in realization	–
GA that codes residual amount of components	– don't include the specifics of zones + better convergence + reduced redundant cost	– small share of solutions in aggregated Pareto-set + better convergence + no redundant costs	–
GA that encodes Pareto-optimal solutions of the zone coverage by detectors	–	–	+ no redundant costs + highest convergence + take into consideration all solutions created by Pareto zones – complicated in realization

4.1. Results of the comparative analysis of the proposed method based on GA compared to the other methods

As you may notice from the table 6, limited search, that take place goes on through realization of the heterogeneous morphological matrix, is significantly faster in comparison with full search, that allows to use it for optimization of the small alarm systems. Although, the time required for the large alarm systems optimization of is still too big (4 hours).

Table 6

Comparative analysis of the proposed method based on GA compared to the other methods

Number of detector models	Number of iterations		Number of Pareto-optimal systems	Execution time			% of Pareto-optimal solutions	
	Full search	Limited search		Full search	Limited search	GA	Search	GA
1	2	3	4	5	6	7	8	9
1	1	1	1	15 ms.	15 ms.	1 sec.	100	100
2	$\approx 3*10^6$	2916	12	7 min.	422 ms.	20 sec.	100	100
3	$\approx 196*10^{12}$	8	2	4.6 day	15 ms.	1 min.	100	100
4	$\approx 3*10^{12}$	$\approx 10^6$	509	6 years	7.8 min.	3 min.	29	64
5	$\approx 196*10^{12}$	$\approx 15\cdot 10^6$	903	433 years	4 hours 5 min.	3 min.	7	39
6	$\approx 603*10^{12}$	$\approx 15\cdot 10^6$	178	1382 years	24 min.	3 min.	47	53

The convergence of all the analyzed algorithms (Full search, Optimized search and two GAs) was tested on a middle-sized model problem with 4 alternative detectors. The Fig. 5 shows the dynamics of Pareto-optimal solutions part, found by the analyzed algorithms.

From the figure it can be seen, that "Full search" algorithm has the lowest convergence. It remains at null percents of Pareto-optimal solutions part during the whole hour. The "Optimized search" oversees indexes of Pareto-optimal zone installations and has significantly better convergence in comparison to "Full search". All the genetic algorithms provide even better convergence during the first hour. GA with chromosomes, that code minimal by sufficient amount of detectors ("GA with residual amount reflection"), provides wider part of Pareto-optimal solution in comparison to search algorithms. But the best convergence is obtained using GA with the reflection scheme of the optimal zone installation indexes, which is proposed in the current study. This scheme uses the same set of Pareto-optimal installations of zones as the "Optimized search" does, but it is converging faster due to the better randomization properties of the GA permutation in comparison to simple step-by-step gradual search.

The advantage of the proposed method of convergence can be summarized as 75%–20% = 55%, where 75% is a part of Pareto-solutions generated by the proposed method and 20% is a part of Pareto-solutions generated by the best search method. So the method, developed in the current study, provides us with the additional 55% of Pareto-optimal structures of the alarm system. The advantage in acceleration can be calculated as the delay between moments, where “Optimized search” and “GA with optimal…” reaches 75% of final Pareto set, i.e. 3.6 hours – 1 hour = 2.6. In percentage to the whole execution time (4 hours) we get 2.6 / 4 = 65%. So the proposed reflection method is 65% faster than the best search algorithm.

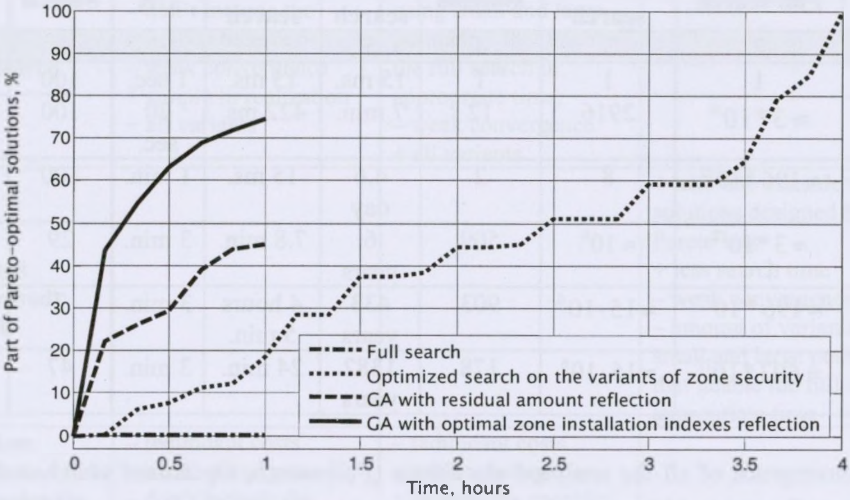

Fig. 5. Convergence dynamics
Rys. 5. Dynamika konwergencji

The proposed method was used to optimize the real-life alarm system. Values for all the criteria can be seen in the table below.

Table 7

Real-life example of the alarm system optimization

No. of variant	Criteria			Detectors	Central	Visualization
	Q_{SVS}	R_{SVS}	C_{SVS}, US $			
41	0.03	0.171	7750	31 units of 3-th model	Integra 32	LCD
83	0.25	0.035	6750	15 units of 1-st model	SA-64	LCD
27	0.25	0.218	5388	8 units of 1-st model 8 units of 4-th model 2 units of 6-th model	SA-64	LCD
84	0.12	0.159	6200	7 units of 1-st model 1 unit of 2-nd model 11 units of 3-rd model	SA-64	LCD

5. Conclusions

This study analyzes the convergence and other properties of four algorithms (full search, optimized search and two genetic algorithms) that solve a problem of the alarm system structure optimization. A new method that involves reflecting chromosome of the genetic algorithm into the problem's domain was developed. The method takes into consideration perimeter of the territory and multiobjective target function. In contrast to the classical genetic algorithm and search schemes the method limits its lookup to the set of Pareto-optimal variants of detector installations, allowing accelerating the optimization process to 65% and increasing the quantity of resulting Pareto-optimal alarm system structures to 55%.

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Omówienie

Zwykle firmy, które instalują systemy alarmowe, korzystają z typowych rozwiązań szablonowych, które nie zawsze są najlepsze (niedostosowane do konkretnego obwodu terytorium). Dlatego projektowanie systemu alarmowego, który zapewnia kompromis między ceną a wydajnością dla wprowadzonego terytorium, jest aktualnym problemem. Rozwiązania tego problemu mogą być organizowane na dwa sposoby: (i) optymalne wykorzystanie elementów systemu alarmowego oraz (ii) modyfikacja elementów.

Pierwszy sposób składa się z metod projektowania, które zapewnią tworzenie całego systemu alarmowego z wymaganą wydajnością i minimalnymi kosztami. Drugi sposób (nieprzedstawiony w niniejszym artykule) obejmuje projektowanie nowych komponentów systemów alarmowych, które mają lepsze parametry niż poprzednie, lub modyfikację istniejących elementów, która wymaga mniej wysiłku.

Metoda projektowania systemów alarmowych, proponowana w tym artykule, bierze pod uwagę geometrię obwodu terytorium jako zamkniętego wielokąta i generuje struktury systemów alarmowych przez stosowanie wielokryterialnej optymalizacji, przy użyciu kryteriów: (i) prawdopodobieństwa fałszywego alarmu, (ii) prawdopodobieństwa niewyjawienia intruza oraz (iii) wartości systemu.

Problem optymalizacji systemu alarmowego może być przedstawiony jako wielokryterialna funkcja celu z ograniczeniami. Właściwości danej funkcji nie pozwalają na używanie zwykłych metod gradientowych do jej rozwiązania, dlatego zanalizowano metody kombinatoryjnej optymalizacji i pokazano przewagę metod ewolucyjnych.

Przedstawiono analizę konwergencji i innych właściwości czterech algorytmów (pełnego wyszukiwania, zoptymalizowanego wyszukiwania oraz dwóch algorytmów genetycznych), które rozwiązują problem optymalizacji struktury systemu alarmowego.

Zaproponowano nową metodę, która polega na odzwierciedleniu chromosomu algorytmu genetycznego w obszar domeny systemów alarmowych. Metoda bierze pod uwagę obwód terytorium i wielokryterialność funkcji docelowej.

W przeciwieństwie do klasycznego algorytmu genetycznego i innych systemów wyszukiwania optymalnego rozwiązania metoda ogranicza wyszukiwanie do zbioru Pareto-optymalnych wariantów instalacji czujników, co przyspiesza proces optymalizacji i zwiększa liczbę wynikających Pareto-optymalnych struktur systemów alarmowych.