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ALGORITHM FOR THE CONSTRUCTION AND OPTIMIZATION OF THE TERRITORIAL LOCATION OF SOUND SOURCES OF EMERGENCY NOTIFICATION SYSTEMS OF THE POPULATION

The article is devoted to the development of an algorithm for solving the problem of optimizing the territorial placement of elements of the public emergency notification system according to the criterion of maximizing the coverage of the territory of the settlement with the permissible power level of sound signal sources based on the application of genetic algorithms.

The relevance of the article is due to the need to improve modern systems of emergency notification of the population, especially in cases where it is necessary to take into account the characteristics of certain territories. This problem is quite important in today's world of permanent emergency situations, and the high-quality distribution of emergency notification sources can become one of the important elements of the system of warning and timely response to disasters.

One of the most effective technologies for building such systems is the use of genetic algorithms, which ensure the search for the most effective options in a dynamic mode with the possibility of their further optimization. Therefore, the development and improvement of methods of rational placement of sources and optimization of the technical characteristics of the system of emergency notification of the population is an urgent problem for the safety and preservation of the health of the population.

The purpose of this article is to develop an algorithm for structural optimization of the territorial placement of sound signal sources of the public emergency notification system according to the criterion of maximizing the coverage of the territory of the settlement with the permissible power level of sound signal sources based on the modification of the genetic algorithm.

In accordance with the proposed approach, the function of maximum coverage of the territory of the settlement with a minimum number of sound signal sources of permissible power is used as an optimization criterion. In the process of searching for the optimal structure of the territorial arrangement of elements of the notification system, a modified genetic algorithm of analysis and determination of the most effective options is used. As a condition for building an optimal solution to the problem, the condition of complete coverage of the territory of the population with sound warning signals is defined.

According to the results of the conducted research, it was found that the developed algorithm allows determining the optimal structure of the territorial placement of sound signal sources of the emergency public notification system based on the criterion of maximizing the coverage of the territory of the settlement with the permissible power level of the sound signal sources.

Key words: *genetic algorithm, algorithm for placement of sound signal sources, optimization of the public notification system.*

Пасічник А. М., Ріпа М. Ю. Алгоритм побудови та оптимізації територіального розміщення звукових джерел системи екстреного оповіщення населення

Стаття присвячена розробці алгоритму вирішення задачі оптимізації територіального розміщення елементів системи екстреного оповіщення населення за критерієм максимізації покриття території населеного пункту із допустимим рівнем потужності джерел звукових сигналів на основі застосування генетичних алгоритмів.

Актуальність статті обумовлена потребою у покращенні сучасних систем екстреного оповіщення населення, особливо у випадках необхідності врахування особливостей певних територій. Ця проблема досить важлива у сучасному світі постійних надзвичайних ситуацій, а якісний розподіл джерел екстреного оповіщення може стати одним із важливих елементів системи попередження та вчасного реагування на катастрофи.

Однією із найбільш ефективних технологій побудови таких систем є застосування генетичних алгоритмів, які забезпечують пошук найбільш ефективних варіантів в динамічному режимі з можливістю їх подальшої оптимізації. Тому розробка і удосконалення методів раціонального розміщення джерел та оптимізації технічних характеристик системи екстреного оповіщення населення є актуальною проблемою для безпеки та збереження здоров'я населення.

Метою даної статті є розробка алгоритму структурної оптимізації територіального розміщення джерел звукових сигналів системи екстреного оповіщення населення за критерієм максимізації покриття території населеного пункту із допустимим рівнем потужності джерел звукових сигналів на основі модифікації генетичного алгоритму.

У відповідності із запропонованим підходом в якості критерія оптимізації використовується функція максимального покриття території населеного пункту при мінімальній кількості джерел звукових сигналів допустимої потужності. В процесі пошуку оптимальної структури територіального розміщення елементів системи оповіщення застосовується модифікований генетичний алгоритм аналізу та визначення найбільш ефективних варіантів. В якості умови побудови оптимального розв'язку задачі визначено умову повного покриття території розміщення населення сигналами звукового оповіщення.

За результатами проведених досліджень встановлено, що розроблений алгоритм дозволяє визначити оптимальну структуру територіального розміщення джерел звукових сигналів системи екстреного оповіщення населення за критерієм максимізації покриття території населеного пункту із допустимим рівнем потужності джерел звукових сигналів.

Ключові слова: *генетичний алгоритм, алгоритм розміщення джерел звукових сигналів, оптимізація системи оповіщення населення.*

Problem's Formulation. Overview of modern emergency notification systems population indicates a wide range of various modern technologies for them buildings However, among the main shortcomings of the existing systems it is worth noting that characteristics of the notification sources not always correspond to their locations placement, or that in general distribution of sources of certain part of cities is insufficient or excessive. Insufficient coverage of the territory can lead to lower speed of the population's reaction to an emergency event, and excessive the level of sound signals can cause health deterioration of people. Therefore, it is necessary to use combinations of common sources emergency notification and mass media: Internet, television, radio and others [1]. If the issue of mass media to some extent is decided, the placement of emergency notification sources needs to take into account a greater number of factors: energy supply, territorial features of the city, population and others. So the power of the notification sources has to be provided from several supply options, since sources without permanent access to energy supply will be limited by the left number of energy, and those that connected only to the main power grid in general may not work during problems with energy supply [2, 3]. Also, the effectiveness of emergency systems notification directly depends on the effectiveness of their interaction with people. According to this, the development of methods of rational placement of sources and optimization of the technical characteristics of the public emergency notification system is an urgent problem for the safety and health of the population.

Analysis of recent research and publications. Currently for resolution of various optimization problems have been widely used modifications of genetic algorithms. In which are used partially modified principles of the genetic evolution and selection, and the main advantage is the possibility of solving rather complex problems of a large size, which do not allow to build an exact analytical solution. Genetic algorithms are effectively used to build solutions to problems of searching of local extrema, both differentiated and undifferentiated functions [4, 5].

The works [6,7] also note the importance of the evolutionary approach for improving the quality of results by using new generations of the population, where each generated generation will give better result and protect algorithm from stopping at certain optimal local solutions.

From recent advances there is an increase in the variety of methods for crossovers and mutations, that are used in different types of problems for improving the quality of results and the speed of obtaining them [8].

A genetic algorithm can be adapted to solve a problem of maximum coverage of a certain territory of the settlement by means notifications taking into account the specifics of their locations and other criteria systems.

Formulation of the study purpose. The purpose of this work is to develop an algorithm for solving the optimization problem of territorial placement of sound signal sources of an emergency alert system for the population, based on the criterion of maximizing the coverage area of the locality with an acceptable power level of sound signal sources.

Presenting main material. To build an effective emergency alert system for the population, it is important to solve the problem of optimal placement and determination of the number of sound signal sources of acceptable power. The optimization criterion chosen is the maximum coverage area of the locality with a minimum number of sound alert sources of acceptable power. To solve this problem, it is proposed to apply a genetic algorithm, according to which:

1. Definition and preparation of the information presentation of the structure and area of the settlement, fig. 1. The start of the coordinate system coincides with the geometric center of the city territory, as shown in fig. 1.

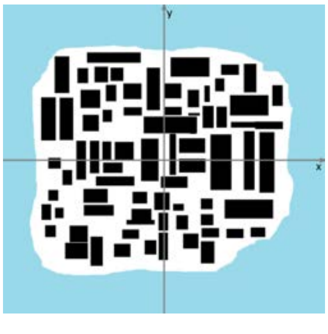

Fig. 1. Structural scheme of the settlement

The corresponding information base should reflect the following parameters of the city territory: population of the territory – black color; possible locations for sound signal sources – white color; places where no devices can be placed – blue color.

The area of the settlement S_v is determined as the area of the closest geometric figure or taken from existing reference data. In most cases, for the software implementation of the algorithm, it is suggested to approximate the area of the settlement by a polygon, whose area is found as the sum of the areas of corresponding triangles. For this, a point inside the polygon is chosen, and it is divided into n triangles. Then, the area is found using Gauss's formula:

$$S_v = \frac{1}{2} \left| \left(\sum_{i=1}^{n-1} x_i y_{i+1}\right) + x_n y_1 - \left(\sum_{i=1}^{n-1} x_{i+1} y_i\right) - x_1 y_n \right|, \quad (1)$$

where n – number of sides of the polygon; (x_0, y_0) – coordinates of a fixed point inside the polygon; (x_i, y_i) i=1, 2, …, n – coordinates of the vertices of the polygon.

In specific cases, when the shape of the territory can be approximated by a circle, the area of the settlement is approximately calculated by the formula:

$$S_v = \pi * ((x_r - x_0)^2 + (y_r - y_0)^2), \quad (2)$$

where (x_0, y_0) – coordinates of the center of the circle; (x_r, y_r) – coordinates of a point on the circle.

Locations of people to whom it is necessary to ensure the arrival of warning signals are determined by the set of coordinates of their location points in accordance with the parameters of the settlement structure:

$$P = \{ (x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n) \}, \quad (3)$$

where (x_i, y_i) – corresponding coordinates of the points of the territory of population placement.

The distance of effective propagation, or the radius of action of sound signal sources for the warning system, taking into account the influence of various criteria, is calculated by the formula:

$$r = r_0 * 10^{\frac{p_0 - p - h*k_1 - E*k_2}{20}} \quad (4)$$

where p – expected minimum sound pressure at the limit of operation of the warning source r, cannot exceed the initial sound p_0 (the maximum permissible value of p_0 is 100 – 105 dB); r_0 – initial distance, 30 m is recommended; h – height of the source location; k_1 – coefficient of influence of height; E – power supply capacity; k_2 – power supply influence factor.

Note, that the radius of the sound signal determines the coverage area of the notification system. The expected minimum sound pressure at the working limit of the warning source cannot exceed the initial permissible regulatory value. The results of the calculation of the dependence of the radius of action of the sound signal on the value of its power are shown in table 1.

Table 1

The distance of propagation of sound signals

p_0, (dB)	80	85	90	95	100	105	110
r, (m)	168	300	533	948	1687	2935	5334

The initial minimum number of warning sources q for the system is determined by the formula:

$$q = \frac{S_v}{\pi * r^2}, \quad (5)$$

where S_v – area of the settlement; r – radius of action of the warning sources.

The value of q must be an integer greater than or equal to 2, otherwise the problem has a trivial solution with the placement of the sound signal source in the geometric center of the territory.

2. To generate the first set of combinations of coordinates for the placement of warning sources (x, y), several such coordinates are combined into a genotype O, a set of such genotypes is combined into a population V:

$$V = [O_1, O_2, \ldots, O_n], \quad (6)$$

$$O_n = [(x_1, y_1), (x_2, y_2), \ldots, (x_q, y_q)], \quad (7)$$

where O_n – is a representative of the population; n – number of individuals in the population; (x_m, y_m) – coordinates of the points of placement of sources; q – number of notification sources.

Thus, the genotype combines the coordinates of all points of possible placement of alert sources into a single list. The highest adaptability, according to this algorithm, will be in the genotype in which the total area of coverage around the warning sources will cover the largest area of population placement P at a given sound signal level p.

For each genotype, the adaptability coefficient reflects the number of population locations that fall within the sound signal coverage area. The initial value of the coefficient of adaptability of the genotype O_n is assumed to be zero: $K_{O_n} = 0$ and according to the formula

$$K_{O_n} = K_{O_n} + 1, \quad (8)$$

only those points (x_i, y_i) of the set P are counted that satisfy the condition

$$\sqrt{\left(x_j - x_i\right) + \left(y_j - y_i\right)^2} \le r\ , \tag{9}$$

where (x_i, y_i) (i=1, 2, … , n) – coordinates of the i-th point from the set P of population locations; (x_j, y_j) (j=1, 2, … , m) – coordinates of the j-th point from the set of O locations of sound signal sources; r – radius of action of the warning sources.

The greater the value of K_{O_n} for each genotype, the greater its adaptability.

3. Conducting a spatial crossover. The initial (parental) pair (O_1, O_2) with the largest value K_{O_n} is selected from the population V. An arbitrary point is chosen on the map of the settlement area in fig. 1 and all points of a circle with a radius r around it are calculated. All points O_1 located in this circle and points O_2 located outside are combined to generate a new genotype (offspring). If the number of points in the new genotype is greater than q, then the extra points with the least adaptability are removed. This step is performed several times to determine pairs of the most fit genotypes.

4. Carrying out genetic operations of mutation of each representative with a certain probability will work regardless of other parameters:

– Mutation. A random genotype O is selected from the population V, a random point is selected in it (usually with a small adaptability), its coordinates are changed to other random ones within the available coverage area. It is recommended to set the probability of such a mutation to 5 – 10 %.

– Modified mutation. A random genotype O is selected from the population V, in which one random value is added to the coordinates of a random point, so that the point is shifted by a small distance. It is recommended to set the possibility of such a mutation to 10 – 20%.

Further, new adaptability values for each genotype are calculated using formula (8). The best of them are selected for inclusion in the next O generation.

5. Analysis of the fulfillment of the criterion of optimal coverage and conditions for termination of the work of the genetic algorithm.

If, after several cycles of the genetic algorithm, the optimal coverage criterion will not be met, then it is necessary to increase the indicator q by 1 and add one arbitrary point to each genotype. The optimal coverage criterion has the following form:

$$S_v \le (S_1 + S_2 + \ldots + S_n), \tag{10}$$

where S_v – area of the city; S_i (i=1, 2, …, n) – area of coverage of the territory by warning sources with radii of action r.

Now it is checked whether the value of K_{O_n} of the most adapted genotype is equal to the number of points of the set P.

If this condition is not met, the algorithm continues its work, again moving to point 4. Otherwise, the transition to the next stage is performed.

6. Checking for the need to optimize the obtained solution. The radii of all warning sources are checked for intersection using the ratio:

$$\sqrt{\left(x_2 - x_1\right)^2 + \left(y_2 - y_1\right)^2} \le r_1 + r_2\ , \tag{11}$$

where (x_1, y_1) and (x_2, y_2) – are the coordinates of the locations of the warning sources, and r_1 and r_2 – are the radii of the action.

In the case when condition (11) is not fulfilled, the radii of the notification sources do not intersect and additional optimization is not required.

Otherwise, there is a possibility of reducing the radius of action of the warning sources. Based on the relation (4), this can be done by reducing the power E or the placement height h. The reduction must be carried out until the adaptation factor K_{O_n} of this warning system is equal to the number of points of the set P.

Let's consider the model problem of placing sources of sound signals with a power of 105 dB for a settlement whose structural scheme can be approximated by a circle with a radius of 5500 meters. In this case, the ratio of the area of the territory of settlement to the area of coverage of one source with a power of 105 dB, in accordance with the data in Table 1, is equal to 3.51. That is, it is necessary to determine the locations of 4 sources of sound signals. The results of the calculation of the location coordinates are shown in Table 2, the scheme of their placement is shown in fig. 2.

Analysis of the given data on fig. 2 shows, that the proposed approach allows optimize resource costs and provides an acceptable notification mode for the population with a permissible sound pressure level of 105 dB, which reduces negative impact on health.

Table 2

Coordinates of the locations of sound signals of the notification system

Coordinates of the locations	Sound source number			
	1	2	3	4
x, (m)	1325	-1625	-1570	1115
y, (m)	1120	1325	-1220	-1120

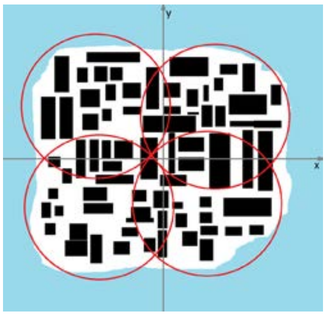

Fig. 2. Scheme of placement of four sources

Conclusions from this study and prospects for further research in this direction. The results of the research allow us to conclude that the developed algorithm allows us to determine the optimal locations of sound signal sources of the public emergency notification system, taking into account the permissible parameters of its operation. The search for the optimal accommodation option is carried out on the basis of maximizing the coverage of the area of the inhabited locality, taking into account the permissible level of power of sound signals. In the future, it is necessary to consider the possibility of building a system of emergency notification of the population using sources of different power and optimizing their locations.

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