Abstract

The article is devoted to the visualization of measuring experiments, visual analysis and estimation of vibration processes to make decision in complicated operational conditions.

The time series analysis of vibratory state nondestructive testing of power facilities of dynamic object of hydro power station is connected with the assessment, comparison and sensing of technological, normative and operational information. Significant and informative visualization of information helps to estimate the technological condition of controlled object faster and more accurately, to research the cause-and-effect relations of influence and two-way influence of power equipment working simultaneously.

Recurrent diagrams for visualization and visual analysis of experimental time series help to imagine the graphic pattern of the researched process as a square matrix with topology and texture. The graphic patterns of experimental time series prove their information value, especially in case of detection of rare events.

The dynamics control algorithms of complicated systems and reflexive choice, based on the application of visual advantages of recurrent diagrams were suggested and described.

The application of recurrent diagrams in ergative systems of control, analysis and interpretation of vibratory processes requires the development of visual thinking skills of the one, who makes a decision

Keywords: *control, vibration, visualization, decision making*

Розглянуто існуючі підходи до вирішення задачі розподілення каналів у системах мобільного зв'язку. Запропоновано трьохетапний метод розподілення каналів у системах мобільного зв'язку. Наведено результати його застосування на прикладі Філадельфійської ЗРК та їх порівняння з існуючими методами

Ключові слова: генетичні алгоритми, штучні нейромережі, системи мобільного зв'язку, задача розподілення каналів, імітація отжигу

Рассмотрены существующие подходы к решению задачи распределения каналов в системах мобильной связи. Предложен трехэтапный метод распределения каналов в системах мобильной связи. Приведены результаты его применения на примере Филадельфийской ЗРК и их сравнение с существующими методами

Ключевые слова: генетические алгоритмы, искусственные нейросети, системы мобильной связи, задача распределения каналов, имитация отжига

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APPLICATION OF THREE-STAGE METHOD OF CHANNELS DISTRIBUTION IN MOBILE COMMUNICATION SYSTEMS

D. Bulavin
Ph.D., Associate Professor of V.N. Karazina Kharkov National University
E-mail: dimetroid@yandex.ru
Contact tel: 099-983-89-99

O. Vysochyna
Ph.D., Associate Professor of Computer Science
East Ukrainian National University named after Vladimir Dal
E-mail: vysochyna_olesya@mail.ru
Contact tel: 050-623-71-04

1. Introduction

Due to the rapid growth of mobile communications engineers faced the channels assignment problem in mobile communication systems. Currently, there is a trend to increasing the number of mobile phone users. And since the frequency spectrum is not infinite, the effective use of frequency channels is becoming more and more difficult problem. Depending on operational requirements the allocated spectrum is divided into channels. To support a large load on the mobile telephone services it is necessary to allocate channels to minimize interference, when re-using them. Simultaneously, these channels are increasing system capacity, in connection with which there is a channels assignment problem (CAP), which is NP-complete, i.e. dimension of the problem increases not polynomially, but exponentially. [2,3].

One option for increasing the efficiency of the frequency spectrum is a cellular approach. This approach divides the space of a wireless coverage area in the hexagonal cells.

In addition to the basic requirements, in practice, additional specification often appears. For example, extension or rescheduling of the existing distribution radio system scheme with a minimal amount of changes in the designated channels or designing a new scheme of wireless mobile network with the growing number of subscribers (traffic) in the future. Thus, it comes down to minimizing the number of channels used, although sometimes let us assume a compromise between the project objectives relative to their priority.

This problem belongs to the class of combinatorial optimization problems based on graph coloring and hence is NP-complete. Using full exhaustive search, as a solution to this problem is almost impossible because of the exponential growth of the temporary resource. Classical methods of graph theory give acceptable results in most cases, but they have several disadvantages:

1. The high degree of indeterminacy (eg, traffic) complicates the process of finding solutions.
2. The absence of an alternative choice of priority planning condition, if there is no final result in full satisfaction of all requirements.
3. The graphs approach covers part of the task, since it only reduces the frequency spectrum which is used, whereas in practice there is an alternative option of using the reserved bandwidth, for example, the channel local reservation to ensure the future growth of the network.

To eliminate the above disadvantages an approach similar to the problem of optimizing the objective function is used. In this formulation, the problem can be solved by most optimization algorithms.

In this article an analysis of channels assignment methods in mobile communication systems was done. In particular: neural networks, for example: Hopfield network, self-organizing networks, and also method of simulated annealing. As a result of the analysis a three-stage method based on evolutionary and heuristic algorithms was proposed and described.

2. Statement of the Problem

The N hexagonal cells in the middle each of them is a base station (BS) with omni-directional antenna are considered. [2, 4]. Each BS can work on any available channel, marked as $c_k (k=1,2...C)$. Let us assume that the interference between any pair of cells are known, i.e. restrictions are set on the frequency separation, which eliminates cross interference and interference from neighboring channels. The channels restrictions are shown as matrix X :

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1N} \\ x_{21} & x_{22} & \cdots & x_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N1} & x_{2N} & \cdots & x_{NN} \end{bmatrix},$$

where $x_{ij}(i,j=1,...,N)$ - the required frequency separation between channels assigned to cells i and j, and to keep the restriction level below certain boundary.

Using matrix X we can represent cross-interference restrictions and interference from neighboring channels by selecting appropriate values for x_{ij} elements. Let's consider the case of cross-interference, when the elements of matrix X take the following meaning: $x_{ij}=1$ if the cells cannot use the same channel, else $x_{ij}=0$.

To solve the channels assignment problem it is necessary to know the required number of channels for each cell. Let λ_i the intensity of admission to the calls for i cell, and μ is subscriber's call servicing. Then determining the proportional number of channels t_i for i cell is defined by Erlang-B formula satisfying subscriber service level P_b. We mark T channels vector with elements t_i $(i=1,...,N)$, which is showing the number of channels for i cell [4]. Let us define the channels assignment problem condition. C of channels and N of cells are given, for each of them set t_i channels. Find an optimal channels assignment matrix with $N\times C$ dimension:

$$A=\begin{bmatrix} 1 & 0 & \cdots & 1 & \cdots & 0 \\ 1 & 1 & \cdots & 0 & \cdots & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & \cdots & 0 & \cdots & 0 \end{bmatrix},$$

where $a_{ik}=1$ if on i cell using c_k channel, else $a_{ik}=0$.

Channels assignment is acceptable if implemented traffic and interference restrictions are made. I.e. satisfies the identity $\sum_{k=1}^{C} a_{ik}=t_i$ for all i; and if c_k and c_l channels, assigned to i and j cells, then $|c_k-c_l|\geq x_{ij}$.

3. Existing methods for solving the channels assignment problem

There are such methods as: neural networks, simulated annealing. to solve the problem of minimizing the interference. Among the neural networks using Hopfield network and self-organizing network are used [1]. Several researchers proposed Hopfield network for solving optimization problems. This is a fully connected neural network with a symmetric matrix of connections. During the process, the dynamics of such networks converges to one of the equilibria positions. These positions are local minima of the Lyapunov energy function.

Consequently, Hopfield neural network can be considered to be an algorithm for optimizing the objective function in the form of the network energy. This is the case to solve the problem of channels assignment, when it is necessary to reduce interference.

An efficient method for the simulation consists of two alternative steps (fig. 1). The first step tries to correct the interference by selecting the current solution, based on the constraints hyperplane of the problem. The second step uses the projection and clipping algorithm network solutions fixed on the constraints hyperplane, i.e get valid solutions.

Used a convergence step for managing algorithm speed Δt. It is three strategies to reduce the time of its execution: with constant Δt, with variable Δt (direct dependence from the approximations to the extremum of energy function) and with Δt, depending on the number of algorithm iterations.

It should be noted that the second strategy both solves the problem quickly and provides the best solutions for static channels assignment. The third strategy gives the best solutions only in some cases, possibly because of the chaotic behavior of the network with large values of the convergence step.

Such chaotic behavior prevented falling into local minimum.

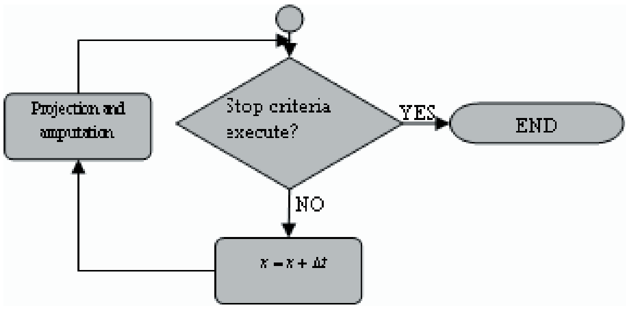


Fig. 1. Hopfield network simulation method

Simulated annealing – general algorithm of combinatory optimization – systematically applied to some forms of channels assignment in the planning of radio networks. This algorithm is based on modeling the physical process that occurs during the crystallization of the substance. It is assumed that, firstly, the process proceeds at decreasing temperature, and secondly atoms in the material already line up in a crystal grid, but the transitions of individual atoms from one cell to another are still impossible. The probability of these transitions, in turn, is caused by temperature: the lower the temperature, the lower the probability. Stable crystal structure of the substance corresponds to the minimum energy value.

This means that an atom either goes into a state with a lower level, or remains in place. The simulated annealing algorithm can be expressed as the following simplified block diagram (fig. 2):

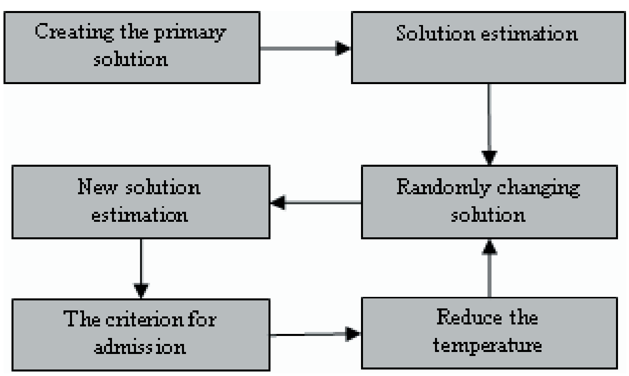


Fig. 2. Block diagram of the simulated annealing method in the general form

Many variants of the method of annealing have been developed, at the present time, both general and particular, for specific problems solutions. During the changing of dimensionality problem face the problems of temporary efficiency and quality of solutions. This is corrected by modification of the transition operations for the network topology.

Compared with the full exhaustive search the above methods have advantages in finding optimal solutions speed. Various modifications to the transition operators let avoid local extremas in the problem space solution. But the main disadvantage is still the solutions quality. The found solution is not always final, there may be conflict with the restrictions.

We consider heuristic algorithms solving the channels assignment problem in a mobile network. The main disadvantage of neural networks is increasing the simulation time for large dimensions of the problem. Simulated annealing algorithm spends less time by using simple operations, but not always immediately gave the optimal solution.

4. Three-stage solving CAP method

The method for solving the CAP problem by combining heuristic and genetic algorithms this article considers. This tandem will eliminate redundant operations in search of the optimal solution.

The proposed algorithm is based on the detection of a partial solutions subset that can be further improved. The given algorithm consists of the following steps:

1. The channels interval identification stage.
2. The fields search stage.
3. The evolutionary strategy stage.

The first stage assigns channels cell by means of which the lower limit of total number of channels was determined. This cell has the largest number of active subscribers, compared with the others. The appointment begins with the first channel, each channel is assigned to follow the same distance from the previously selected channel, taking into account inter-channel interference. The second stage determines the network area with the largest number of subscribers, and assigns them to channels. These areas are composed of cells with high levels of active subscribers and the neighboring cells. If on the second stage there appear conflicts in the channels assignment, then the algorithm expands the scope to involve the neighboring cells. Then again the channels are reassigned, and if the second phase is completed successfully, we proceed to the distribution of channels using evolutionary strategies. Otherwise, we still go to the third stage, basing only on the information gathered on the first stage.

The inputs to the algorithm are: compatibility matrix C, demand vector D, cluster size N_c and interference constraints CCC, ACC and CSC.

The algorithm continues iteratively to repeat in the cycle until it comes to the optimal solution, or the maximum number of generations is exceeded. In the evolutionary strategy not only persons in the neighboring cells are considered, but also solutions from other cells, which significantly reduces the probability of getting in the local extremum, which occurs in other CAP algorithms solving.

The interaction of elements on the third stage of the proposed algorithm with the following input parameters are illustrated in fig. 3: demand vector, compatibility matrix, frequency range and the results of the first and second stages. Strategy for distribution by the frequencies is used only for subscribers who have not been given frequency.

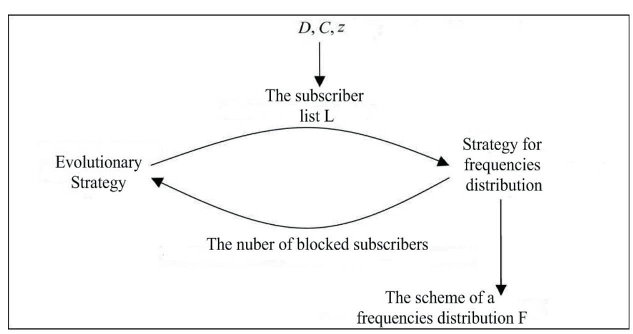
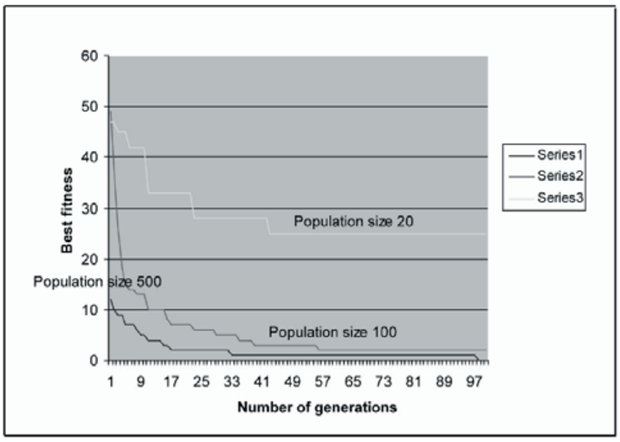


Fig. 3. Evolutionary strategy and channels assignment strategy

This algorithm was realized in MatLab with the help of Genetic Algorithm Toolbox.

The choice of parameters. In evolutionary strategies, there are several parameters that affect the process of finding the optimal solution. In particular, it is a measure of population size, mutation probability, the number of selected parents and the probability of crossover [4-5]. ES are used for CAP solving in our application. Several tests, based on these parameters were made. The general picture of ES behavior is shown on fig. 4.

The results reflected a combination of heuristic algorithms and evolutionary strategies. This tandem provides with practical advantage in the search for optimal solutions and to increase the search speed compared with other methods, such as neural networks, which require many calculations, even in the simplest cases. In addition, the algorithm finds the optimal or near optimal solution in connection with the use of the genetic properties on the third stage. All this testifies to the fact that this algorithm is very efficient and powerful tool for finding CAP solutions.



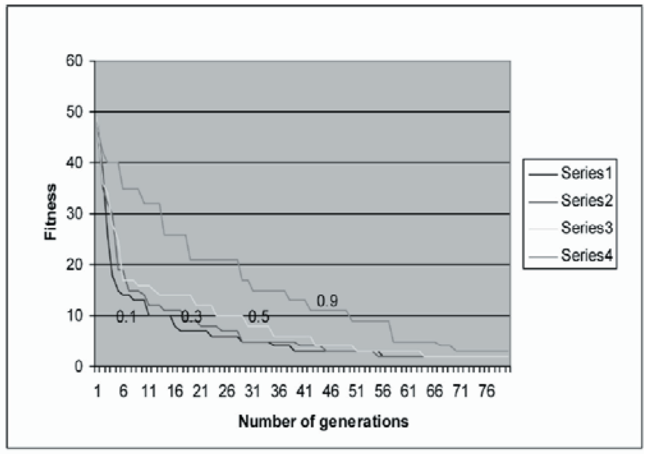


Fig. 4. a) population size and evolutionary strategy convergence; b) the probability of mutation and evolutionary strategy convergence

We can observe that the manipulation of parameters makes the rate of algorithm convergence increase. However, the optimal choice of these parameters depends on the task. There were no patterns to determine the best setting values. You can also select fixed settings according to the test results and change it every time when the algorithm can not find an optimal solution. But as it can be seen from the results, the algorithm is not very sensitive to the settings parameters and gets the same results for all the selected parameters. This is an important advantage comparing with the existing options-dependent algorithms, such as "simulated annealing" [1].

Simulation results. Simulation of the algorithm was held at Intel Core 2 Duo processor T7500. The condition of Philadelphia CAP was taken for comparison and the results were compared with other algorithms. As a result of simulation the canonical genetic algorithm did not find a single solution of this problem, then we chose the simulation results of Sivarajan algorithm and Funabiki neural network. [6].

The results of different CAP algorithms modeling are shown in Table1. As we can see from the results, in 11 from 13 experiments lower bound solution was successfully found. The tests show that in simple cases 3-8 and 10-13 we can find the optimal solution with the help of the first two stages of the proposed algorithm, or with one or three generations in the third stage. The productivity is satisfactory. Besides it takes no more than a few seconds. But on the other hand cases 1, 2, 9, 10 in the third stage require not less than 200 000 generations to find the optimal solution. Computing time can take to 10 hours. This is explained by the fact that the algorithm is implemented in MatLAB and not suitable for its matrix optimization, but using of parallelization would not solve the problem, since the system is optimized for matrix computations.

Table 1

Task Number	Lower bound	Sivarajan algorithm	Funabiki neural network	Proposed algorithm
1	427	460	427	432
2	427	447	427	432
3	533	536	533	533
4	533	533	533	533
5	381	381	381	381
6	381	381	381	381
7	533	533	533	533
8	533	533	533	533
9	253	283	258	253
10	253	269	258	253
11	309	310	309	309
12	309	310	309	309
13	529	529	529	529

5. Conclusion

The algorithm for solving NP complete problem of the channels assignment in a cellular mobile communication system was considered. This algorithm combines heuristics methods with genetic algorithms. The three-stage algorithm searches the optimal solution by defining the lower boundary of the frequency, channels distribution in the busiest cells, and improving the results obtained by using evolutionary strategies. On the first stage channels are assigned at regular intervals in the cell, which determines the lower boundary of the number of channels. On the second stage search for the busiest areas and the distribution of these channels is held. If the second stage fails, you should go to the third stage based on the results of the first phase.

The testing was conducted in the framework of Philadelphia CAP, the results were compared with Funabiki neural network and Sivarajan algorithm. The algorithm calculated the lowest boundary in 11 of 13 cases. According to the results the algorithm can be considered effective and very powerful tool for solving the problem of channels assignment.

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Abstract

To maintain the heavy demand on the mobile telephone services it is necessary to single out the channels and minimize the drawbacks at reutilization. At the same time, these channels increase the system capacity; therefore, the channel allocation problem arises, which is NP-complete, i.e. the dimension of the problem increases not polynominally, but exponentially.

The article analyzes the methods of channels distribution in the mobile communication systems, in particular of neural networks illustrated by Hopfield net, of self-organizing networks and of simulated annealing method. According to the results of analysis, the three-stage method, based on the evolutional and heuristic algorithms, was suggested and described

Keywords: *genetic algorithm, artificial neural network, mobile communication systems, problem of channels distribution, simulated annealing*