Development of Decision-Making Automated System for Optimal Placement of Physical Access Control System’s Elements

Olga Danilova\textsuperscript{1} and Zinaida Semenova\textsuperscript{2}

\textsuperscript{1}Omsk State Technical University, 11, Mira av., Omsk, 644050, Russia
\textsuperscript{2}Siberian State Automobile and Highway University, 5, Mira av., Omsk, 644080, Russia

\textsuperscript{1}E-mail: olga.danlot@yandex.ru,
\textsuperscript{2}E-mail: semenova.z.v@gmail.com

Abstract. The objective of this study is a detailed analysis of physical protection systems development for information resources. The optimization theory and decision-making mathematical apparatus is used to formulate correctly and create an algorithm of selection procedure for security systems optimal configuration considering the location of the secured object’s access point and zones. The result of this study is a software implementation scheme of decision-making system for optimal placement of the physical access control system’s elements.

Keywords: system of physical protection, physical access control system, decision-making system, optimization problem.

1. Introduction

One of the most effective and civilized approaches for solving complex objects security problems is the use of physical protection systems (PPS), including a set of access control instruments (ACI), security television (ST) and fire-protection equipment (FPE). It should be noted that the problem of optimal placement of the PPS elements is at the stage of pre-project researches, and the decisions taken at this stage determine the quality and reliability of the PPS.

Formulation of the optimization problem and applied methods depend on the degree of parameters’ uncertainty, the system operates. There are four types of tasks. The first ones are the problems with the determined parameters, and needed solutions are continuous or discrete [1]. Problems of the second type are the problem of decision-making under risk, characterized by the fact that the exact values are unknown for a number of parameters, but ranges of change are identified [2]. The third type suggests that the possible discrete values are given for each of the parameters, for which the performance coefficient values, associated with each of alternative solutions, are determined [3]. The fourth ones differ from above mentioned in that decision is based on analytics in the competitive environment of the opposing sides, and game model is used as a decision-making scheme [4]. The choice of optimization method depends on the criteria and limitations as well as the degree of discrete parameters and availability of information about their probability distribution laws.

Any optimal solution search algorithm for the problem of minimizing the function on a set are aimed at solving a particular class of optimization problems with certain properties of the functions.
and set. Therefore, a more universal algorithms aimed at solving a wide range of problems, yield specialized algorithms, using the specific properties of specific problem. So one of the first optimization methods is the exhaustive search method. Partial enumeration methods, methods of cuts, approximations methods, methods of local optimization are often used among the approximate methods [5].

The model testing includes an assessment of its consistency, sensitivity, relevance and performance. Consistency requires a logical analysis of the modeling results by varying the initial parameters. Optimization calculations’ results are assessed in detail for the limit values of the parameters. The sensitivity analysis is based on changes in system’s performance and efficiency at the highest variations of controlled parameters. One of the relevance testing method is to establish correspondence of modeling results to well-known special cases. The efficiency of the model is related to the resource estimate required for the collection of baseline and to conduct computer experiments [6].

The authors of this paper believe that it is possible to determine the rational distribution of the protection systems’ elements based on the analysis of the access points and zones organization on the object. Integrated physical access control system (PACS) was chosen as the object of the study in the work.

2. Formulation of the problem
The developed decision-making system (DMS) has to provide the collection and processing of the input data; displaying, recording and further archiving information for later use. The main purpose of the DMS is the need to maintain a record of information about the object’s state and dynamics. The accumulated data can be processed automatically for subsequent tactical and strategic analysis for management of decision-making process [7].

The initial data for the DMS development is the information about the elements and a set of minimum requirements for the characteristics of the security features on each element.

First, the system has to carry out a survey for the object’s category determination, and after the actual configuration of the system is made.

Using the data a request to create an optimal system configuration for determined object’s category is generated. At this stage we solve the problem of an optimal system configuration construction. After determination of the optimal and actual system configuration it is necessary to perform a comparison to detect critical differences.

3. The theory
The problem of rational arrangement of elements in the security system is divided into three parts: the problem of choosing the optimal configuration; PACS elements location task on the access object and the problem of optimal allocation of resources between the parts of the system.

The problem of choosing the optimal configuration is formalized as follows: a finite set of all possible elements of the PACS \( F \) is considered divided into a number of \( G, Q, P \) subsets, each of which corresponds to a plurality of components of the system. The statement of the optimization problem is simple and natural. There are the optimization problem and the individual optimization problem. Let define the individual optimization problem for PACS is a pair \((G_1, c)\), where \( G_1 \) is a set, the range of permissible values of identifiers subset, and \( c \) is the value of the function providing the mapping \( c: G \rightarrow \mathbb{R}_+ \). It’s needed to find a point \( g_1 \in G \), for which \( c(g_1) \leq c(y) \), for all \( y \in G \). This point is a globally optimal solution for a given individual optimization problem. Mathematical formalization of individual tasks leads to the answer to the question: which of the \( i-th \) solutions is optimal one and does it meet the requirements of the relevant class system? The optimum element is an element meet the conditions \( c \{i\} \times x \{i\} \rightarrow \min \).

Problems of an arrangement of elements on the object and resources distribution are solved using of provisions of the graph theory. Each object is represented as one enclosed zone i.e. including variants of other zones. Access points on the object are determined as vertices, and transitions between these points of access – as edges of the graph, i.e. overlaps of access zone. For each edge the category of access, it corresponds, is defined. While the treelike scheme building it is necessary, considering a
priority of categories of access (the general application, important, especially important), to define a category of access points on the object [8].

To solve the problem of resource allocation it is required to convert the edges weights of the weighted bipartite graph in the way, that each vertex has to become incident to at least one edge with zero weight, and weights of all the edges in this case weren’t negative. Empty matching \( M \) is declared as current one. If the graph vertices are saturated with respect to the current matching, the current matching is optimal. If not, then it’s needed to choose any free \( b \in B \) vertex and look for \( M \) – alternating chain that begins at the \( b \) vertex, and consists only of zero-weight edges. Once such chain is constructed, the \( M = M \oplus P \) operation is performed, and it is checked whether all the vertices are saturated with respect to this matching or not. If the chain is not built, for the \( b \in B' \), \( a \in A' \) vertices set, marked in the search process, \( d = \{ \min c(b, a) \mid b \in B', A \in A \setminus A' \} \) is determined and \( (B', d, A') \) operation is applied to the graph. From the \( b \in B' \) vertices, which was incident to at least one zero-weight edge, search of \( M \)- alternating chain with only the zero-weight edges is resumed. If such a \( P\)-chain is built, the \( M = M \oplus P \) operation is performed again and the saturation peaks is checked. And it continues until an optimum matching is found.

4. Experimental results

The solution of the above problems allows determining the approaches to the automation system design (AS) ensuring the collection and processing of information, used for decision-making on the compliance of the proposed PACS project with the real operating conditions of the informatization object.

Analysis of the structural scheme of access zones on the object is based on the formation of \( c \) access points of PACS and defined as a \( C \) set, which owns the \( (c \in C) \) access points. If the object has several structural units with different categories of access to each of them, considering the specifics of the functional features of the object, then the PACS has several subsystems with different categories of access zones, and consequently, different levels of user access (access subject). Then the \( C \) set is divided into \( I \) subsets of \( C_i \) with the \( c_i \) elements. \( \{ C_i \subset C \mid i = 1, ..., I \} \) are subsets of \( C \) set. Subsets of \( C_i \) access points can be overlapping or nonoverlapping. This depends on whether there are the structural units of the common access zone and points or not. The totality of all \( z \) PACS access zones can be defined by a variety of \( Z \) to which the \( z \in Z \) access points belong. In turn, the \( Z \) set, in general, divided into \( J \) of \( Z_j \) subsets with \( z_j \) elements. \( \{ Z_j \subset Z \mid j = 1, ..., J \} \) is a proper subset of \( Z \).

For formation of access zones it is necessary to submit the physical access control system on the object in the form of a graph. One of the main objectives of the placement is to create the best conditions for the implementation of access control functions. Each access point must be equipped with a certain set of elements, which by its characteristics must comply with this access category.

5. Discussion of results

The main module of the DMS is the databases for the correct design of which the corresponding infological model is developed. The basic structural elements of infological models are the entities, links between them and their properties. The entities in this case are the sets of the technical elements of the PACS, and the properties (attributes) - their technical characteristics. Each entity must define a key that is the minimum set of attributes from the values of which the desired entity instance can be unambiguously found. Then the corresponding database tables are formed, and a query structure is made on which during operation of the automated system temporary tables needed for the task are created. The block diagram of the considered DMS is shown in Figure 1.
To make a decision it is necessary to perform the following operations:

1. The minimum requirements for the elements of the system are defined, considering the recommendations of the technical standards. Each solution is stored in a special database by categories: access control, ST, FPE, DMS. Under each configuration the specific solutions are selected.

2. The request to the category and structure of the object based on the presence of zones of different object types are made. Then, the DMS allows choosing the optimum configuration of the system and makes the distribution of elements on the object.

3. The selected configuration of PACS to meet the optimum one is analyzed.

6. Summary
As a result of the research the questions of design of new security systems and the analysis of existing design decisions have been considered Domain analysis allowed formulating requirements for security systems, defining the main blocks of the decision-making algorithm on the optimal placement of PACS elements.

The practical significance of the work is based on the fact that the results of access control systems design on the basis of the developed approaches will meet the necessary criteria for the significance of the object category, considering the cost of the planned system.
References

[1] Alekseev V Yu 1987 Complex application of methods of discrete optimization
[2] Aho A, Hopcroft J, UllmanJ and Aho M 1979 Construction and analysis of computational algorithms
[3] Emelyanov V V, Kureichik, V M 2003 Theory and practice of evolutionary
[4] Pankratiev E V, Chepovsky A M 2003 Algorithms and methods for solving scheduling problems and other extremum problems on large-scale graphs Fundamental and Applied Mathematics 9 (1) p 235-251
[5] Fedorov V V 1971 The theory of optimal experiment (planning of regression experiments)
[6] Balazs E 1969 Additive algorithm for solving linear programming problems with the variables taking values 0 and 1 New episode 6 p 217
[7] Berner L I, Garmash V B, Levin M Sh, Antropov M V 1985 Formation of valid options hierarchical control systems at the design stage. Problems and methods of decision-making: Coll. Works p 62-72
[8] Chen. B, Potts C N and Woeginger G J 1998 A review of machine scheduling: Complexity, algorithms and approximability. Handbook of Combinatorial Optimization 3