http://doi.org/10.35784/iapgos.3031

received: 19.06.2022 | revised: 24.08.2022 | accepted: 15.09.2022 | available online: 30.09.2022

MANAGEMENT OF THE WORKPLACES BY THE FACILITIES OF OPERATIONS RESEARCH

Nataliia Geseleva[1], Ganna Proniuk[2], Olexander Romanyuk[3], Olga Akimova[4], Tetiana Troianovska-Korobeynikova[3], Liudmyla Savytska[3], Saule Rakhmetullina[5], Nurbapa Mekebayev[6]

[1]State University of Trade and Economics, Department of Digital Economy and System Analysis, Kyiv, Ukraine, [2]Kharkiv National University of Radio Electronics, Department of Occupational Safety, Kharkiv, Ukraine, [3]Vinnytsia National Technical University, Vinnytsia, Ukraine, [4]Vinnytsia National Technical University, Department of Pedagogy and Vocational Education, Vinnytsia, Ukraine, [5]D. Serikbayev East Kazakhstan Technical University, Ust-Kamenogorsk, Kazachstan, 6 Kazakh National Women's Pedagogical University, Almaty, Kazachstan

Abstract. *The optimal location of workplaces plays an important role in the structure of occupational safety. The design of the workspace should ensure the optimal distribution of functions between person and machine in order to create safe working conditions, reduce the severity of work and the level of production injuries. Most often, workplace planning is carried out manually, by simple calculation, and then the rationality of workplace planning is evaluated, based on statistics of industrial accidents and occupational diseases, as well as indicators of labor productivity, for example, the ratio of compliance with norms. To solve the problem of optimal placement in the work mathematical models are built that can take into account various regulatory restrictions and are simple for further software implementation. It is proposed to choose the theory of φ-functions as a basis, which can be characterized as measures of proximity of objects. Thus, the set task of optimal placement of workplaces is reduced to the task of mathematical programming. The objective function determines the criterion of optimality – the minimization of the area or perimeter that will be occupied by the objects. This formulation of the problem is relevant because the use of the smallest production area, taking into account safety requirements, is an economic condition for effective production management. The constraint on the relative location of workplaces is set using φ-functions, which defines the decision domain. That, when formalizing restrictions, you can take into account all regulatory safety distances between workplaces, equipment, walls, etc. Thus, the work explores an approach that will allow automatic planning of the placement of a large number of technological objects, workplaces in accordance with occupational safety standards. Use of the software application, which can be implemented on the basis of the φ-functions apparatus, will significantly reduce the time of workplaces planning and increase its efficiency.*

Keywords: occupational safety, working place**,** φ-functions, occupational ergonomics, operations research

ZARZĄDZANIE MIEJSCEM PRACY ZA POMOCĄ BADAŃ OPERACYJNYCH

Streszczenie*. W strukturze ochrony pracy ważną rolę odgrywa optymalna organizacja miejsc pracy. Projektowanie przestrzeni roboczej powinno zapewnić optymalny podział funkcji pomiędzy człowieka i maszynę w celu stworzenia bezpiecznych warunków pracy, zmniejszenia uciążliwości pracy i poziomu urazów odniesionych w pracy. Najczęściej planowanie miejsca pracy odbywa się ręcznie, poprzez proste obliczenia, a następnie ocenia się racjonalność planowania miejsca pracy na podstawie statystyk urazów i chorób zawodowych, a także wskaźników wydajności pracy, na przykład współczynnika zgodności z normami. Do rozwiązania problemu optymalnego rozmieszczenia budowane są modele matematyczne, które mogą uwzględniać różne ograniczenia normatywne i są proste do dalszej implementacji programowej. Proponuje się wybór teorii funkcji φ, którą można scharakteryzować jako miarę bliskości obiektów. W ten sposób problem optymalnego rozmieszczenia miejsc pracy sprowadza się do problemu programowania matematycznego. Funkcja celu określa kryterium optymalności – minimalizację obszaru lub obwodu, który ma być zajęty przez obiekty. Takie postawienie problemu jest istotne, ponieważ wykorzystanie najmniejszej powierzchni produkcyjnej, z uwzględnieniem wymogów bezpieczeństwa, jest ekonomicznym warunkiem efektywnego zarządzania produkcją. Ograniczenia wzajemnej lokalizacji miejsc pracy ustalane są za pomocą funkcji φ, co określa domenę decyzyjną. Tak więc przy formalizowaniu ograniczeń można uwzględnić wszystkie normatywne odległości bezpieczeństwa między miejscami pracy, urządzeniami, ścianami itp. W związku z tym w artykule badane jest podejście, które będzie automatycznie planować rozmieszczenie dużej liczby obiektów technologicznych, miejsc pracy odpowiednio do standardów bezpieczeństwa pracy. Zastosowanie oprogramowania, które może być realizowane na bazie funkcji φ, znacznie skróci czas planowania miejsc roboczych i zwiększy jego efektywność.*

Słowa kluczowe: ochrona pracy, miejsce pracy, funkcja φ, ergonomia miejsc pracy, badania operacyjne

Introduction

The issues of workplace ergonomics in safety play an important role. Equipment and organization of the workplace must ensure that all its elements and the mutual position of all workplaces according with ergonomic requirements, taking into account the nature and characteristics of work. Production equipment should be installed, located and used in the way to reduce risks for operators and other workers (sufficient space between moving and stationary parts of equipment or moving parts around it, safe supply and disposal of all energy and substances used or produced). Workers must have safe access to all areas intended for operation, regulation and maintenance, as well as the ability to safely stay in them and safely leave these areas.

At the same time, occupational safety and environmental protection requirements are basic, and are present in every sphere of human activity. Many of them boil down to the fact that objects should be placed in a limited area, as close (further) as possible to each other or to some fixed objects, with restrictions on the pairwise minimum (maximum) distance, the presence of prohibition zones, etc. Forbidden areas may be residential buildings, reserves, sanitary zones, landscape elements and other areas. Objects can be, for example, hazardous production, waste disposal, noise and vibration generators, or simply workplaces of PC users and light sources [7].

Under the workplace is understood as a place equipped with means of displaying information, management and auxiliary equipment, where the work of a specialist is carried out. The organization of the workplace is called a system of measures to equip the workplace with tools and objects of labor and their placement in a certain order to optimize the working conditions, security, maximum efficiency and reliability of human.

The standard approach in the occupational safety system to the placement of workplaces is as follows: specialists study all the requirements for the size of workplaces, their mutual placement and manually draw up a layout. However, often there are problems of planning a large number of workplaces in a limited space. This paper proposes a formalized approach to the organization of workplaces, which can be used when planning the placement of objects of various purposes and shapes. There are several ways to solve this problem, in this paper it is proposed to use the mathematical apparatus of operations research, namely, the construction of φ-functions, which can be characterized as a measure of the proximity of an object.

The tasks of optimal placement of objects – one of the most important classes of problems in the operations research. Their applications arise in various fields of science and technology, and take of great practical importance. When placing technological equipment, enterprises and other objects of the real world, as a rule, it is required to locate them on a smaller area, not chaotically, but with observance of a certain order, taking into account the many restrictions dictated by state regulations.

The purpose of this work is to apply the formal apparatus of operations research, namely φ-functions, to solving the problem of workplaces placing, taking into account all occupational safety requirements. The proposed model can be easily implemented programmatically using any modern applications and languages, which will allow you to automatically receive a layout of production facilities in the shortest possible time, which takes into account various safety requirements and will be cost-effective, as it allows to reduce production resources, which is certainly interesting from a practical point of view.

1. Formulation of the problem

The correct organization of the workplace should ensure, firstly, the safety of work, and secondly, high labor productivity. When designing a workplace, it is necessary to proceed from the analysis of a specific labor process performed by a person on this equipment, take into account the anthropometric data of a person, sanitary and hygienic working conditions.

The main role among ergonomic indicators belongs to anthropometric parameters, which determine the conformity of the equipment to the size and shape of the human body, the distribution of his mass. The design of the workplace should provide such physical loads for the worker, in which the energy consumption of the human body during the working day would not exceed 1046.7 kJ/h [5].

At the same time, the equipment should be able to support the work process that eliminate the monotony of job by limiting the frequency of simple repetition processes and the duration of continuous monitoring. Production equipment has to provide the necessary space to operator for any of its positions.

The rational layout of the workplace provides a comfortable working posture, the possibility of using advanced techniques and methods of work, minimal trajectories of movements of the worker, objects of labor, which prevents premature fatigue and a decrease in labor productivity. At the same time, the placement of workplaces and equipment on it must comply with the norms and requirements for occupational safety. In modern conditions at enterprises this issue is solved by a safety specialist, based on theoretical calculations in each specific case (taking into account the production tasks performed, the technologies used, etc.). This approach takes a lot of time, especially when planning large industrial premises, and does not exclude the appearance of calculation errors.

Subsequent estimation and rationalization of the layout of the workplace are carried out on the basis, for example, of the occupancy rate of the production area or during the certification of the workplace (on average once every 5 years). The occupancy rate of the production area is calculated as the sum of the ratios of the norms of the area occupied by the equipment element to the area of the workplace according to its layout (should be in the range of 0.4–0.65).

Thus, the task of the study is to apply the mathematical apparatus of operations research to the problem of workplace placement, which allows you to automatically obtain the optimal placement in accordance with the specifics of production, taking into account the requirements of regulatory documents on safety.

The use of the proposed mathematical apparatus will speed up the planning of workplaces, help save enterprise resources and guarantee a safe organization of the workplace and high work productivity.

2. Theoretical research

Placement problems, as the most important class of optimization geometric design tasks, determine the optimal position of a finite set of geometric objects of arbitrary spatial shape in given areas of placement in the presence of various restrictions and quality criteria and related to geometric information processing. The beginning of the development of approaches to modeling and solving problems of optimal placement, especially the problems of cutting and packaging, was laid by the works of L.V. Kantarovich, B.A. Zalgaller, Yu.G. Stoyan, P. Gilmore and others.

Development of geometric design, thanks to the works of the scientific school Yu.G. Stoyan and O.O Yemets, contributed to the creation in the 1990s of Euclidean combinatorial optimization, which allowed the optimal placement of objects using analytical [4] and algorithmic [13] optimization methods on combinatorial sets.

The creation of the theory of optimization geometric design, which is based on the construction and study of various types of mappings of geometric information, allowed to build a mathematical apparatus for modeling such important applied problems as the problem of optimal cutting of industrial materials [5, 6], development of master plans of industrial enterprises, waste management, design and management of complex technical systems, including taking into account physical fields of various nature [3], if the carriers of these fields have an arbitrary spatial shape.

One of the most important stages in the construction and study of mathematical models of such problems is analytical modeling of constraints (geometric constraints, taking into account the spatial shape of objects and areas of location, and constraints due to the peculiarities of this problem, such as constraints on the characteristics of the resulting physical fields, technological constraints, etc.), which highlight the area of acceptable solutions to the optimization problem. Therefore, to solve the problems of these classes it is necessary to develop tools for modeling the basic geometric constraints, namely, the conditions of mutual non-intersection of objects and their affiliation to the location, based on the apparatus of φ-functions [10].

The objects to be placed are divided into many simplest geometric objects, such as a rectangle, a polygon and a circle. Using the theory of φ-functions, a decision tree is constructed, the leaves of which are independent linear programming tasks. Each such subtask consists of an objective function and a system of linear constraints, operating with a measure of the proximity of objects and implementing the constraints of the model. Introduce the some definitions.

An object T_i, translated on a vector u_i is denoted as

$$T_i(u_i) = \{X \in R^n | X = u_i + Y, Y \in T_i\}, \tag{1}$$

where $u_i \in R^n, n = 2, 3$ is the vector of parameters of object placement T_i, $i = 1,2$.

A continuous and everywhere defined function

$$\varphi : R^{2n} \to R^1, n = 2, 3, \tag{2}$$

is called φ-function of objects $T_1(u_1)$ and $T_2(u_2)$ if it satisfies the following characteristic properties [17]:

- $\varphi(u_1, u_2) > 0$, if $cl\,T_1(u_1) \cap cl\,T_2(u_2) = \varnothing$,
- $\varphi(u_1, u_2) = 0$, if $\operatorname{int} T_1(u_1) \cap \operatorname{int} T_2(u_2) = \varnothing$ and $fr T_1(u_1) \cap fr T_2(u_2) \neq \varnothing$,
- $\varphi(u_1, u_2) < 0$, if $\operatorname{int} T_1(u_1) \cap \operatorname{int} T_2(u_2) \neq \varnothing$.

Due to the fact that it is of interest to locate workplaces (for example tables), i.e. objects of rectangular shape, then we give an example of constructing a φ-function for two rectangles. The task of optimal placement of workplaces is reduced to the problem of mathematical programming. The objective function determines the optimality criterion – minimizing the area or perimeter occupied by objects. Restrictions on the mutual arrangement of tables are set with the help of φ-functions, and describe the scope of the solutions search.

Let the rectangles $R_1(u_1)$ and $R_2(u_2)$ be given by the length $2a_1$, $2a_2$ and width $2b_1$, $2b_2$ and respectively. Construct a curve γ_{12} – a set of points at which $\varphi_{12}(u_1, u_2)=0$ (as was shown in Fig. 1), so

$$\gamma_{12} = fr\{R_1(0) + (-1)R_2(0)\}. \tag{3}$$

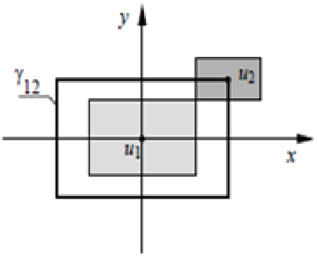


Fig. 1. The curve γ_{12} for rectangles

Consider the equations of four lines that limit γ_{12}:

$$\chi_1(x, y) = x - A, \qquad \chi_2(x, y) = y - B,$$
$$\chi_3(x, y) = -x - A, \qquad \chi_4(x, y) = -y - B, \tag{4}$$

where $A = a_1 + a_2$, $B = b_1 + b_2$.

Thus $T_{12} = \{(x, y) \in R^2\colon \chi_i(x, y) \le 0,\ i=1,\dots,4\}$, and therefore:

$$\gamma_{12} = \left\{(x, y) \in R^2\colon \chi(x, y) = \max_{i=1,\dots,4} \chi_i(x, y) = 0\right\} \tag{5}$$

The corresponding orientation $\chi(x, y)=0$ is set so that the φ-function of the rectangles takes the form:

$$\varphi_{12}(u_1, u_2) = \chi(x_2 - x_1, y_2 - y_1). \tag{6}$$

It should also be noted that φ_{12} is not normalized [9] since the values of $\varphi_{12}(u_1, u_2)$ are not equal to the distances between the rectangles $R_1(u_1)$ and $R_2(u_2)$ in the general case, namely: in cases when (dx, dy) with $dx = x_2 - x_1$ and $dy = y_2 - y_1$ satisfy one of the following systems:

$$\begin{cases}\chi_1(dx, dy) > 0\\ \chi_2(dx, dy) > 0\end{cases} \quad \begin{cases}\chi_2(dx, dy) > 0\\ \chi_3(dx, dy) > 0\end{cases}$$
$$\begin{cases}\chi_3(dx, dy) > 0\\ \chi_4(dx, dy) > 0\end{cases} \quad \begin{cases}\chi_4(dx, dy) > 0\\ \chi_1(dx, dy) > 0\end{cases} \tag{7}$$

For construct a normalized φ-function of two rectangles $R_1(u_1)$ and $R_2(u_2)$ it is necessary to introduce some additional functions:

$$\tilde{\chi}_1(x, y) = x+y-s, \qquad \tilde{\chi}_2(x, y) = -x+y-s, \tag{8}$$

$$\tilde{\chi}_3(x, y) = -x-y-s, \qquad \tilde{\chi}_4(x, y) = x-y-s, \qquad s = A+B, \tag{9}$$

$$\varphi_1(x, y) = \sqrt{(x-A)^2 + (y-B)^2},$$
$$\varphi_2(x, y) = \sqrt{(x+A)^2 + (y-B)^2}, \tag{10}$$

$$\varphi_3(x, y) = \sqrt{(x+A)^2 + (y+B)^2},$$
$$\varphi_4(x, y) = \sqrt{(x-A)^2 + (y+B)^2}. \tag{11}$$

Then we have

$$\varphi_{12}(0, 0, x, y) = \omega(x, y) =$$
$$= \max\left\{\max_{i=1,2,3,4} \chi_i(x, y),\ \max_{i=1,2,3,4} \min\{\varphi_i(x, y), \chi_i(x, y)\}\right\} \tag{12}$$

Normalized φ-function $R_1(u_1)$ and $R_2(u_2)$ takes the form

$$\varphi_{12}(u_1, u_2) = \omega(x_2 - x_1, y_2 - x_1). \tag{13}$$

Thus, the optimization problem was formulated, and constraints were chosen to model the optimal placement of workplaces (rectangular tables) in the minimum area.

3. Experimental research

It is proposed to solve the obtained system of linear equations (8–12) with the help of a simplex-method, which provides a fast working time for tasks of small and medium dimension. In the future, the solution of the obtained system of linear equations will give the opportunity to correctly locate workplaces in the minimum area in compliance with all the rules and regulations.

The proposed solution to the task of optimal placing of workplaces can have several interpretations. It depends on the choice of the optimization function and the specifics of the setting requirements. For example, you need to minimize the space between a few geometrical objects. In this case, with known geometric dimensions of the given rectangle, this model has the solution shown in the figure 2.

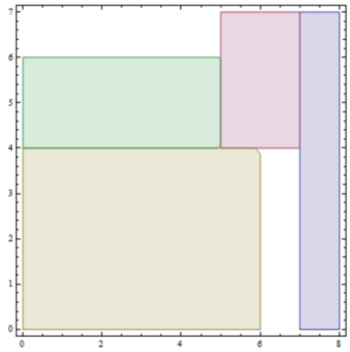


Fig. 2. Example of model realization

Above, we considered the simplest case of placing workplaces (for example, tables). However, this mathematical apparatus is applicable to all the simplest mathematical objects. Consider a situation where the optimization of placement is necessary for the workplace and some equipment [2].

Let the object $R_1^*(u_1)$ and the rectangle $R_2(u_2)$ be known, while R_1^* is characterized by $2a_1$ and $2b_1$. The length $2a_2$ and width $2b_2$ of rectangle R_2 are such that $a_1 \ge a_2$ and $b_1 \ge b_2$. In this case

$$\gamma_{12} = \mathrm{fr}T_{12} = \mathrm{fr}\{R_1^*(0)+(-1)R_2(0)\}, \tag{14}$$

where $T_{12} = \mathrm{cl}(R^2 \setminus \{(x, y) \in R^2\colon -A \le x \le A, -B \le y \le B\})$, $A = a_1 - a_2$, $B = b_1 - b_2$.

Setting,

$$\chi_1(x, y) = A-x,\ \chi_2(x, y) = B-y,$$
$$\chi_3(x, y) = A+x,\ \chi_4(x, y) = B+y, \tag{15}$$

we have

$$D_0 = \mathrm{cl}(R^2 \setminus T_{12}) = \{(x, y) \in R^2\colon \chi_i(x, y) \ge 0,\ i = 1,\dots, 4\} \tag{16}$$

and therefore

$$\gamma_{12} = \mathrm{fr}D_0 = \mathrm{fr}T_{12} = \{(x,y) \in R^2\colon \chi(x,y) = 0\}, \tag{17}$$

where $\chi(x, y) = \min\{\chi_1(x, y), \chi_2(x, y), \chi_3(x, y), \chi_4(x, y)\}$.

Thus, the normalized φ-function of the object $R_1^*(u_1)$ and the rectangle $R_2(u_2)$ takes the form

$$\varphi_{12}(u_1, u_2) = \chi(x_2 - x_1, y_2 - y_1). \tag{18}$$

Suppose that we need to place two round objects $C_1(u_1)$ and $C_2(u_2)$. Let C_1 and C_2 be circles of radiuses r_1 and r_2 respectively (Fig. 3). In this case

$$T_{12} = C_1(0) + (-1)C_2(0) =$$
$$= \{(x, y)\colon \chi(x, y) = x^2 + y^2 - (r_1 + r_2)^2 \le 0\}. \tag{19}$$

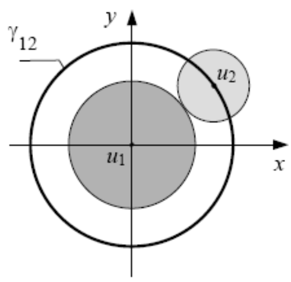


Fig. 3. The curve γ_{12} for objects $C_1(u_1)$ and $C_2(u_2)$

Therefore, the curve $\chi_{12} = \mathrm{frT}_{12}$ can be described by the equation $\chi(x, y) = 0$, i.e. the set of positions of the circle C_2 relative to C_1 is such that the circles are touching [2]. The equation $\chi(x, y) = 0$ according to [10]. Therefore, in order to determine the φ-function, in this case it is sufficient to set the corresponding orientation of the equation $\chi(x, y) = 0$.

Then,

$$\varphi_{12}(0, 0, x_2, y_2) = x_2^2 + y_2^2 - (r_1 + r_2)^2,$$
$$\varphi_{12}(u_1, u_2) = (x_2 - x_1)^2 + (y_2 - y_1)^2 - (r_1 + r_2)^2, \tag{20}$$

where $u_i = (x_i, y_i)$, $i = 1, 2$ – circle broadcast vector C_1 and C_2.

Next, we consider the mutual placement of some object $C_1^*(u_1)$ and the circle $C_2(u_2)$. Let C_1 and C_2 be circles of radiuses r_1 and r_2, and let $r_1 \ge r_2$ (Fig. 4).

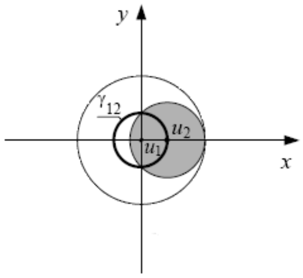


Fig. 4. The curve χ_{12} for object $C_1^*(u_1)$ and circle $C_2(u_2)$

Then,

$$T_{12} = C_1^*(0) + (-1)C_2(0) = \\ = \{(x, y): \chi(x, y) = (r_1 - r_2)^2 - (x^2 + y^2) \leq 0\}. \quad (21)$$

Therefore, the curve χ_{12} can be determined by the equation $\chi(x, y) = 0$. Then,

$$\varphi_{12}(0, 0, x_2, y_2) = \chi(x_2, y_2) = (r_1 - r_2)^2 - x_2^2 - y_2^2, \\ \varphi_{12}(u_1, u_2) = -(x_2 - x_1)^2 - (y_2 - y_1)^2 + (r_2 - r_1)^2. \quad (22)$$

To construct a normalized φ-function of the objects $C_1^*(u_1)$ and $C_2(u_2)$, instead of the function χ, use the function

$$\tilde{\chi}(x, y) = (r_1 - r_2) - \sqrt{x^2 + y^2} \quad (23)$$

then

$$\tilde{\Phi}_{12}(u_1, u_2) = (r_1 - r_2) - \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}. \quad (24)$$

The theory of φ-functions for 3-dimension space is called a φ-polytope [1, 8]. Other objects can be approximated by polygons and polytops, which is a common practice [15, 17, 18].

In the future, the solution of this system of linear equations will give the opportunity to correctly locate workplaces on a minimum area in compliance with all rules and regulations. Further study and application of this mathematical apparatus can help improve the efficiency of production planning [12, 14, 16].

4. Conclusions

Proper placement and layout of workplaces that satisfy the requirements of ergonomics and occupational safety ensure the most productive workflow and reduce employee fatigue. Insufficient organization of workplaces leads to professional burnout, even injuries. The optimal placement of workplaces, which contributes to high labor productivity and the preservation of the health of workers, occupies an important place in occupational safety.

This work is devoted to modeling and solving the general problem of optimizing the workplaces placement, taking into account safety standards. The apparatus of φ-functions was used to solve the stated problem. The optimization problem of workplaces placing according to the criterion of the minimum area of premises is formulated, which is important for ensuring the minimum cost per unit of production (rental cost, energy costs, etc.). To describe the full class of φ-functions required to represent all technological units in the workplace, it is necessary to study each pair of such objects. All elements of the workplace can be conditionally represented as objects of elementary geometric shapes. An interesting problem is the placement of objects of an arbitrary multidimensional shape, which would make it possible to carry out 3D modeling of workplaces for rooms of various configurations. Notice, the considered algorithm is transformed to the problem of packing n-dimensional parallelepipeds. If we consider n-dimensional polygons, then this problem already belongs to the class of NP-hard problems and requires additional study, maybe to involve quasi φ-functions. This approach is currently being studied and may be applied in the future.

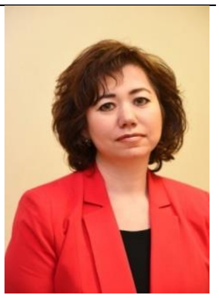
Analytical representation of constraints in the presented optimization problem using φ-functions allows you to set any constraints on the relative position of objects, i.e. take into account all safety requirements when organizing workplaces. For example, according to Normative legal acts on occupational safety of Ukraine No. 0.00-7.15-18 "Requirements on the safety and health of person working with screen devices", workplaces with computers are located at a distance of at least 1 meter from the walls with windows; the distance between the side surfaces of monitors should be at least 1.2 meter; the passage between the rows of tables with PC should be at least 1 meter. All these restrictions are easily added to the mathematical model or removed in the shortest possible time.

This method is easily applicable for software implementation, for example, using the Mathematica environment. In a few seconds, such a program can produce solutions in the form of a layout of the placement of geometric objects. The constructed constraints contain an insignificant number of variables for modern computing systems. In this regard, it is considered that the solution time of the constructed mathematical model is insignificant. Undoubtedly, the effective application of this approach to workplace planning is impossible without a specialist who can correctly formally describe the restrictions, taking into account all the requirements of regulatory documents in the field of occupational safety. Thus, the professional training of an employee has a significant impact on the effectiveness of this technique, in turn, this drawback can be eliminated in software implementation by creating active functionality.

References

[1] Bennell J. A., Oliveira J. F.: The geometry of nesting problems: A tutorial. Europ. J. Operational Research 184, 2008, 397–415.
[2] Chernov N. et al.: Mathematical model and efficient algorithms for object packing problem. Comput. Geometry: Theory & Appl. 43, 2010, 535–553.
[3] Chub I. A., Novozhilova M. V.: Solution of the extreme problem of resource allocation as a problem of placing rectangles with variable metric characteristics. Informatics and System Science. ISS–2011: science–pract. Conf. Poltava, 2011, 331–334.
[4] Emets O. A., Roskladka A. A.: On estimates of minima of criterion functions in optimization on combinations. Ukrainian Mathematical Journal 51(8), 1999, 1262–1265.
[5] Karwowski W, Marras W. S.: Occupational Ergonomics: Principles of Work Design. CRC Press, 2003.
[6] Romanova I. E. et al.: Mathematical model and method for solving the problem of optimization of packing of arbitrary two-dimensional objects in rectangular areas. Reports of the National Academy of Sciences of Ukraine 1, 2009, 48–53.
[7] Stack T. et al.: Occupational Ergonomics: A Practical Approach, Wiley 2016.
[8] Stoyan Y. et al.: Packing of convex polytopes into a parallelepiped. Optimization 54, 2005, 215–235.
[9] Stoyan Y. et al.: φ-function for complex 2D-objects, 4OR: Quarterly J. Belgian, French and Italian Operations Research Soc. 2, 2004, 69–84.
[10] Stoyan Yu. Et al.: Phi-function for primary 2D-objects, Studia Informatica Universalis 2, 2001, 1–32.
[11] Verkhoturov M.A.: The problem of irregular cutting of flat geometric objects: modeling and calculation of rational cutting. Information Technologies 5, 2000, 37–42.
[12] Wójcik W., Pavlov S., Kalimoldayev M.: Information Technology in Medical Diagnostics II. London: Taylor & Francis Group, CRC Press, Balkema book, 2019 [http://doi.org/10.1201/9780429057618].
[13] Yemets O.A., Roskladka A.A.: Algorithmic solution of two parametric optimization problems on a set of complete combinations. Cybernetics and Systems Analysis 35(6), 1999, 981–986.
[14] Vyatkin S. et al.: A GPU-based multi-volume rendering for medicine. Proc. SPIE 11045, 2019, 1104513.
[15] Vyatkin S. et al.: A function-based approach to real-time visualization using graphics processing units. Proc. SPIE 11581, 2020, 115810E.
[16] Vyatkin S. et al.: Offsetting and blending with perturbation functions. Proc. SPIE 10808, 2018, 108082Y.
[17] Vyatkin S. et al.: Offsetting and blending with perturbation functions. Proc. SPIE 11045, 2019, 110450W.
[18] Vyatkin S. et al.: Transformation of polygonal description of objects into functional specification based on three-dimensional patches of free forms. Proc. SPIE 11176, 2019, 1117622.

Ph.D. Nataliia Geseleva
e-mail: gesnata@ukr.net



Ph.D., Associate Professor of Department of Digital Economy and System Analysis, State University of Trade and Economics. Research Interests: system analysis and modeling of processes of economic and technological development, synergistic models of the economy, management of innovative activities.

http://orcid.org/0000-0001-9188-9738

Ph.D. Ganna Proniuk
e-mail: ganna.proniuk@nure.ua

Ph.D., Associate Professor of Department of Occupational Safety and Department of Infocommunication Engineering V.V. Popovsky, Kharkiv National University of Radio Electronics. Research Interests: synergetic approach to the management of working conditions, risk management; modeling of data flows in telecommunication networks. Author of more than 100 publications, including 4 collective monographs, 1 textbook.

http://orcid.org/0000-0001-7648-0360

Prof. Olexander Romanyuk
e-mail: rom8591@gmail.com

Doctor of Science, Professor of the Department of Software Vinnytsia National Technical University. Research Interests: development of highly efficient interpolation methods and tools for machine graphics systems, highly effective rendering methods and tools, methods and structures for parallelization of the computational process in computer graphics.

http://orcid.org/0000-0002-2245-3364

Prof. Olga Akimova
e-mail: sopogov@ukr.net

Doctor of science, Professor, Head of the of the Department of Pedagogy and Vocational Education, Vinnitsa State Pedagogical University. Author of more than 86 publications, including 3 textbooks, 33 patents for inventions and more than 51 scientific articles in professional journals, of which 9 are in scientometric databases Scopus and Web of Science.

http://orcid.org/0000-0001-6988-6258

Ph.D. Tetiana Troianovska-Korobeynikova
e-mail: luydik0304@gmail.com

Ph.D., Associate Professor of the Department of Computer Engineering, Vinnytsia National Technical University.
Research Interests: development of highly efficient interpolation methods and tools for machine graphics systems, highly effective rendering methods and tools, methods and structures for parallelization of the computational process in computer graphics.

http://orcid.org/0000-0003-2487-8742

Ph.D. Liudmyla Savytska
e-mail: luydik0304@gmail.com

Ph.D., Associate Professor of the Department of Computer Engineering, Vinnytsia National Technical University. Research interests: Information technologies.

http://orcid.org/0000-0003-1130-2621

Ph.D. Saule Rakhmetullina
e-mail: Rakhmetullinas@mail.ru

She is currently a Chairman of the Board-rector of the D. Serikbayev East Kazakhstan Technical University. She is a co-author over 40 papers in journals, book chapters, and conference proceedings and has 3 copyright certificates for software products. She is a Republican expert on reforming higher education. Her professional interests are mathematical and computer modeling of complex processes.

http://orcid.org/0000-0002-3142-0249

Ph.D. Nurbapa Mekebayev
e-mail: nurbapa@gmail.com

Associate professor of the Kazakh National Women's Pedagogical University, Head of the Department of Mathematics. About 60 of scientific articles have been published in various foreign and domestic journals. Research area: machine learning, deep learning, artificial intelligence, speech technologies.

http://orcid.org/0000-0002-9117-4369