ГОДИШНИК

НА ТЕХНИЧЕСКИЯ УНИВЕРСИТЕТ

във Варна

Том III

ВАРНА

2013

ГОДИШНИК

НА ТЕХНИЧЕСКИЯ УНИВЕРСИТЕТ
във Варна

Том III

ВАРНА
2013

Издател: Технически университет-Варна
ISSN:1311- 896X

СЪДЪРЖАНИЕ
ТОМ III СБОРНИК НАУЧНИ СТАТИИ

PROBLEMS OF GEOMETRIC DESIGN: PLACEMENT, COVERAGE, PARTITION AND DEFINING OPTIMAL ROUTES

Vladimir Andronov, Valentina Komyak, Alexander Sobol, Vladimir Komyak, Albina Popova

Abstract: In the paper some examples of applied problems fire protection of national economy objects, which reduced in their statements to the class optimal geometric design, are considered. This class includes optimal placement, covering and cutting set of objects, the construction of optimal routes and connecting networks, some scheduling problems, etc. The basic restrictions of the optimal geometric design problems are analyzed. Also results of investigation problem-oriented models are given.

Keywords: geometric design, problem-oriented models.

I. INTRODUCTION

A number of problems requiring to process and transform geometric data emerge in different areas of national economy. These tasks are classified as the problems of optimal geometric design [1]. The development of methods to solve such problems is an important task. These are the following problems: the problem of optimal material cutting (regular and nonregular), the problem of making optimal routes and connecting networks, the problems of covering, placement, partition, some tasks of the theory of schedules etc. [1-2].

II. EXPOZITION

1. Reference study

The problem of placement of geometric objects was initially stated by academic Vladimir Rvachev back in 1963 [3]. Main restrictions of the defined problem of placement were the conditions of objects not crossing the borders of one another and condition of placement of these objects onto a certain plane. The classical example of the placement problem is a problem of material cutting. The solution of the placement problem in this case requires the length of the material piece holding all of the placed objects to be minimal (or maximized coefficient of population) (Fig. 1).

The main difficulty in determining the solution for a given problem is in building analytical description of two conditions. The condition, which constitutes that the borders of objects should not be crossing one another and the condition demanding objects to be placed in a certain area. The first step in building analytical description of these conditions was a method based on *R*-functions, which were introduced in the works of Vladimir Rvachev [3,4]. Established approach was further developed in the works on Yuri Stoyan. In order to formalize non-crossing relationships between objects and quantitative measures to define the degree of fulfillment of these relationships, he established the concept of Φ-functions [5]. Φ- surface of a Φ- function is a hodograph of a vector function of objects dense placement (hereafter referred to as hodograph). Defined hodograph allows transforming geometric data about objects into information about their possible dense placement.

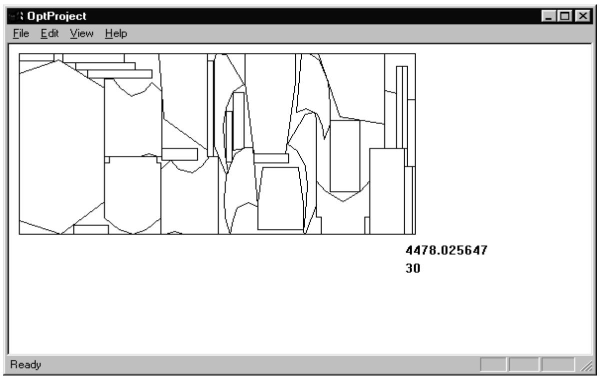

Fig. 1 An example of a solution for the material cutting problem

The strategy of finding a solution for the problems of nonregular placement of object in [6-7] is based on the optimization method by groups of variable using the hodograph to define approximations to local and global extremums. There have been a number of approaches created to determine local and global extremums for cases with nonregular placement of objects with unconditioned shapes [8-9]. A few problems of regular placement of objects were solved. A number of works were dedicated to a problem of objects placement [10-14].

The second important class of geometric design problems consists of tasks to cover an area with geometry objects [15]. In coverage problems the obligatory condition is to have all points in the area covered with geometric objects. The condition of non-crossing borders and the condition of having objects placed on the area can be violated (Fig. 2). Cases with regular and nonregular coverage are considered.

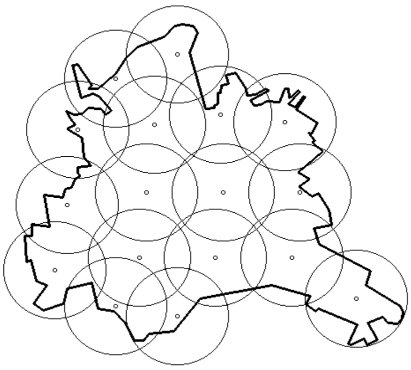

Fig. 2 The solution of a problem to cover Kharkov with 3 kilometer radius circles

The third class of geometric design problems is represented with partition tasks. The tasks of continuous partition of area into geometric objects have been covered in the work [16], and as for the task of discrete problem of partition it has been analyzed in the work [17]. The main requirements of tasks of continuous partition of area to geometric objects (the same as for the coverage tasks) are conditions that the objects should not to be crossing and the condition of having objects placed on the area, but with the additional requirement of being equal to a coefficient unit of the area coverage (picture 3). Methods of regular and nonregular partition are considered. In the work [18] one of the methods of some area regular partition with the help of mutually orthogonal lines based on the example of partition of the cultivated area has been suggested (Fig. 3).

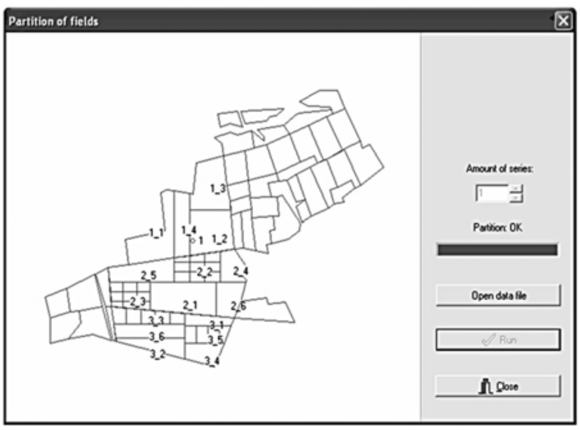

Fig. 3 Partition of cultivated area

Tasks of making optimal routes and connecting nets in non-simply-connected regions (which can be found in works [2,19]) can be considered as the forth class of geometric design tasks. A real process of geometric object placement (coverage, partition of area to objects) is modeled in the geometric design tasks. The modeling is known for various ways of transformation of geometric information, as the result of which the search of an optimal geometric object placement (coverage, partition) is done. The tasks are connected with processing of big volumes of geometric information and considering a big number of various requirements and are beyond the scope of classical theory of operations research. There's the need of grouping the tasks in the separate class of so-called geometric design as the methods of their modeling and solution are non-standard.

2. Main results

The aim of the article is dedicated to the following tasks. There's a need for general principles of object placement, partition and coverage modeling as well as development and research of problem-oriented models, methods, algorithms and software for successful solution of scientific and practical tasks in the industry. Development of problem-oriented models for various subject fields leads to additional technological restrictions changing the main model that results in the necessity of new methods and modification of the existing ones to solve the tasks.

Currently the following tasks have been decided.

2.1. Placement of fire stations in big cities task [21].

The task is defined the following way. Having the given resource, the minimum specified amount of fire stations in order to protect the modeled area of the city (or the whole city) should be defined, as well as the parameters of their placement which enable to reduce the time of arrival of fire department to the possible hot spots.

Decomposition of the task is considered in work [21]. As the result of the decomposition, two main stages of the solution have been defined.

The first stage of the solution is defining the minimum quantity of fire stations, which cover the whole city with circular zones together with the zones of the existing fire stations (Fig. 2), that is the task of arbitrary-shaped area coverage with circles.

The task of rational placement of fire stations is solved for each circular zone of protection during the stage of building design of the area when the main architecture and planning solutions have been defined, and that is the second stage of the solution. The task is reduced to placement of geometric object of the constant size considering standardized maximal and minimal distances between fire station and buildings.

Paper [17] shows us the solution of placement of fire stations as the task of non-regular partition of arbitrary area on geometric objects, which metric characterization are defined with the object diameter that is calculated based on standardized time of arrival to fire area (Fig. 4).

Fig. 4 Partition of Kharkov territory to protection areas

2.2. Task of placement of fire stations for country-side [22].

Rural districts have a range of peculiarities that disable the approaches listed above [17,21]. The peculiarities are: 1) settlements are placed as a rule unevenly; 2) the number of habitats of separate settlements varies essentially; 3) district center where as a rule the fire stations are placed are not usually in the geographical center of the district; 4) existing road network is good regarding connection between settlements and the district center, meanwhile the roads among the settlements are not good enough.

The following task comes from the points above.

Basing on economic feasibility, the parameters of fire protection of the area (the quantity of fire stations and parameters of their placement in the settlements) should be defined; these parameters should minimize the time to get to the possible hot spot. The following restrictions should be taken into account: uneven density of the habitats, density of the housing, special risk objects, the quality of road network that connect settlements within the district; conditions of fire stations in the district of the corresponding settlement. The example of the task solution is shown on Fig. 5.

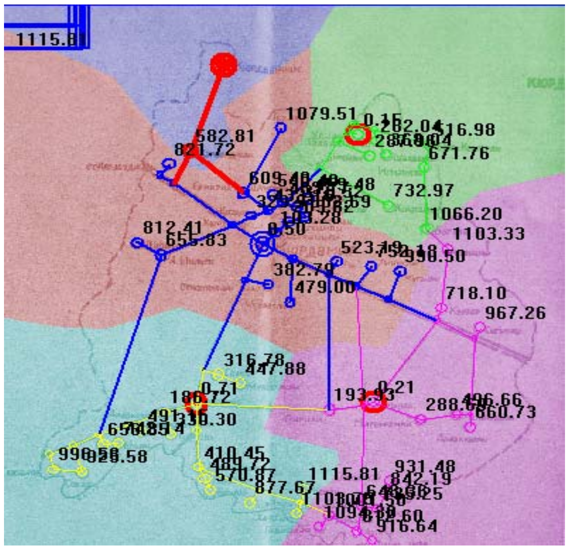

Fig. 5 Optimal placement of five fire stations on the plurality consisting of 62 settlements in Kyurdyamirskiy district, the Republic of Azerbaijan, with the defense area highlighted

2.3. The task of fire hydrant placement [23].

Let’s consider an area of a city where every building should be provided with fire hydrants (FH), which are the source of water supply along the hose lines of the limited length.

Then we have a task to find minimal quantity of FH, placed on the networks routing the water supply in the way so the network that consists of verges going from FH and enveloping each building of the area should satisfy another condition: not to exceed the maximum allowed length along the network from every boundary point of the building to the closest hydrant.

Stated another way, a network with minimum quantity of apexes on some broken curve and with restriction on the length of its verge should be built on the multiply-connected domain.

The task has been solved in placement of FH for protection of buildings in Ordzhonikidzevskiy area of Kharkov (Fig. 6).

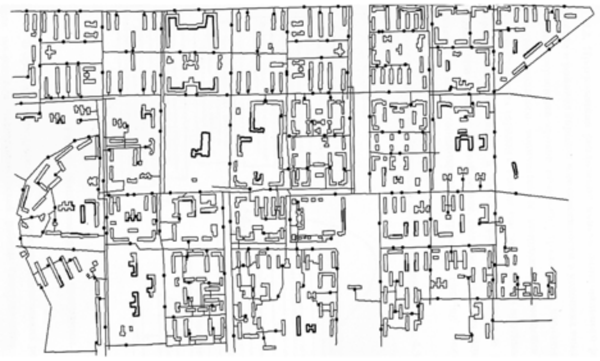

Fig. 6. Placement of fire hydrants (dots on the water supply network) in Ordzhonikidzevskiy area of Kharkov, Ukraine

2.4. The task of cooperation between subdivisions of paramilitary security services of the railroad and rescue fire departments [24].

The problem is important today because emergency situations on the railroad that are accompanied with fires (explosions) of tank-cars containing highly-flammable liquid, liquefied gases and also spread (discharge) of flammable liquid and highly toxic substance, are of a high risk status. What is important to notice is that the main harm in the like cases depends on the reaction time of the rescue teams to emergency situations which happen on the railroad.

The next task is closely connected to the previous one. The minimum quantity of subdivisions of paramilitary security services of the railroad and rescue fire departments that can provide proper reaction to the emergency situations on the railroad should be defined. Whereby all of the following points should be taken into account: the protected railroad areas should be completely covered with areas of existing rescue teams, the overlapping territory should be minimal, the existing service areas, road network, lay of the land, population in the proper settlements, and also restricted area of rescue team placement, and considering attendance time of rescue teams that shouldn't exceed the given one.

The given task has been reduced to the class of tasks describing optimal coverage of the given areas with geometric objects with variable metric characterization, as shapes and sizes of areas where the rescue teams are located are defined with possible places of allocation and existing road network.

The example of the given tasks solved is shown on Fig. 7.

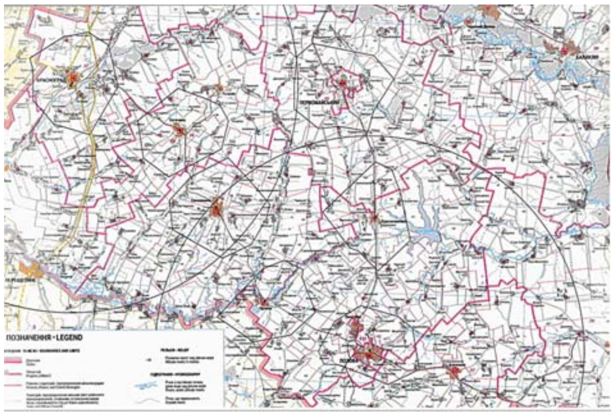

Fig. 7. The result of coverage of the areas of the railroad Krasnograd –Lozovaya – Pervomayskiy, Ukraine, with the areas of rescue team locations

III. CONCLUSIONS

The examples of the tasks solved in the subject area of fire safety have been provided in this work. As said above, the tasks are grouped into various classes of geometric design tasks, which require taking into account the range of additional conditions and as a result there's a need for development of new methods and modification of the existing ones.

Further researches will be dedicated to the following issues:

- development of placement methods of geometric objects with changing metric characterizations;
- development of placement methods of objects with sectionally non-lineal borders;
- ongoing research of ξ-function properties in the class of partition tasks for development of effective modeling methods;
- class of 3D partition, coverage etc.

REFERENCES:

[1]. Стоян Ю.Г. Основная задача геометрического проектирования. – Х.: Ин-т проблем машиностроения АН УССР, 1983. – 36 с. (Препринт/ АН УССР. Ин-т проблем машиностроения; 181)

[2]. Элементы теории геометрического проектирования / [Яковлев С.В., Гиль Н.И., Комяк В.М. и др.]; под ред. В.Л. Рвачева. – К.: Наук. думка, 1995. – 241 с.

[3]. Рвачев В.Л. Об аналитическом описании некоторых геометрических объектов / Доклады АН Украины, 1963. – № 4. – С. 765-767.

[4]. Рвачев В.Л. Геометрические приложения алгебры логики – К.: Техника, 1967. – 212 с.

[5]. Стоян Ю.Г. Об одном обобщении функции плотного размещения / Доклады АН УССР, 1980. – № 8. – С. 70-74.

[6]. Стоян Ю.Г. Гиль Н.И. Методы и алгоритмы размещения плоских геометрических объектов – К.: Наук. думка, 1976. – 248 с.

[7]. Комяк В.М. Математическое и компьютерное моделирование нерегулярного размещения плоских геометрических объектов в областях произвольной пространственной формы: дис. … докт. техн. наук: 01.05.02. – Х., 1996. – 377 с.

[8]. Магас С.Л. Методы решения экстремальных задач размещения многоугольных геометрических объектов на полосе: автореф. дис. … канд. физ. - мат. наук: 01.05.03. – М., 1984. – 20 с.

[9]. Новожилова М.В. Решение задачи поиска глобального экстремума линейной функции цели на структуре линейных неравенств. – Х.: Ин-т проблем машиностроения АН УССР, 1988. – 48 с. – (Препринт / АН УССР. Ин-т проблем машиностроения; 292).

[10]. Dowsland K.A., Dowsland W.B. Packing problems // Europ. Journ. Oper. Res., 1992. - V.56. - P.2-14.

[11]. Li Z., Milenkovic V. A compaction algorithm for non-convex polygons and application // Proc. 9th Annual ACM Symposium on Comp. Geom., May 19-21.-1993.

[12]. Beasley J.E. An exact two-dimensional non-guillotine cutting tree search procedure // Europ. Journ. Oper. Res., 1985. - V.33. - P.49-65.

[13]. Milenkovic V., Daniels K., Li Z. Placement and compaction of nonconvex polygons for clothing manufacture // Proc. International Conf. on. Geom. – Canada, 1992.

[14]. Margues V.M., Bispo C.F. A system for the compaction of two dimensional irregular shapes based on simulated annealing // Proc. International Conf. on. IECON'91 (IEEE), 1991.-P.1911-1916.

[15]. Стоян Ю.Г., Яковлев С.В. Математические модели и оптимизационные методы геометрического проектирования. – К.: Наук. думка, 1986. – 265 с.

[16]. Киселева Е.М., Шор Н.З. Непрерывные задачи оптимального разбиения множеств: теория, алгоритмы, приложения: Монография. – К.: Наук. думка, 2005. – 564 с.

[17]. Садковий В.П., Комяк В.М., Соболь О.М. Раціональне розбиття множин при територіальному плануванні в сфері цивільного захисту: Монографія – Харків.: Ліхтар, 2008. – 173 с.

[18]. Долгодуш М.М. Геометричне моделю-вання раціонального розбиття посівних площ за заданими вимогами: автореф. дис. … канд. техн. наук: 05.01.01. – Мелітополь, 2008. – 20 с.

[19]. Смеляков С.В., Стоян Ю.Г. Моделирование пространства путей в задачах построения оптимальних траекторий // Журнал вычисл. матем. и матем. физики, 1983, № 1.- С.73-82.

[20]. Стоян Ю.Г., Винарский В.Я. Алгебро-топологические свойства φ-объектов. – Х.: ИПМаш АН УССР, 1981. – 34 с.- (Препринт / АН УССР. Ин-т пробл. Машиностроения; 166).

[21]. Коссе А.Г. Метод раціонального розміщення пожежних депо при проектуванні та оновленні районів міста: автореф. дис. … канд. техн. наук: 21.06.02. – Х., 2002. – 19 с.

[22]. Кязимов К.Т. Геометричне моделювання розміщення пожежних підрозділів в сільській місцевості на прикладі Азербайджану: автореф. дис. … канд. техн. наук: 05.01.01. – К., 2010. – 24 с.

[23]. Комяк В.М., Романов Р.В., Панкратов А.В. Модель и метод определения допустимых параметров размещения пожарных гидрантов в районе города // Геометричне та комп'ютерне моделювання. – Харків: ХДУХТ, 2009. – Вип. 25. – С. 27-32.

[24] Комяк В.М., Соболь О.М., Коссе А.Г., Собина В.О. Особливості методу визначення раціональної кількості та місць розташування оперативних підрозділів для захисту об'єктів залізниці // Проблеми надзвичайних ситуацій. Зб. наук. пр. НУЦЗ України. – Харків: НУЦЗУ, 2010. – Вип.11. – С. 74-79.

Contacts:

Vladimir A. Andronov. Department Management and Organization Activities in Field Civil Defense, National University of Civil Defense of Ukraine, Chernyshevskaya str., 94, Kharkov, 61023, Ukraine
Phone: +38-057-704-18-02, +38-057-707-34-72,
Email: andronov@nuczu.edu.ua

Valentina M. Komyak, Department Physics and Mathematics Subjects, National University of Civil Defense of Ukraine, Chernyshevskaya str., 94, Kharkov, 61023, Ukraine
Phone: +38-067-578-98-80,
Email: vkomyak@ukr.net

Alexander N. Sobol, Department Management and Organization Activities in Field Civil Defense, National University of Civil Defense of Ukraine, Chernyshevskaya str., 94, Kharkov, 61023, Ukraine
Phone: +38-068-962-81-39,
Email: uodscz@nuczu.edu.ua, alexander_sobol@i.ua

Vladimir V. Komyak, Department Management and Organization Activities in Field Civil Defense, National University of Civil Defense of Ukraine, Chernyshevskaya str., 94, Kharkov, 61023, Ukraine
Phone: +38-067-570-65-85,
Email: uodscz@nuczu.edu.ua

Albina V. Popova, Department Management and Organization Activities in Field Civil Defense, National University of Civil Defense of Ukraine, Chernyshevskaya str., 94, Kharkov, 61023, Ukraine
Email: uodscz@nuczu.edu.ua

Reviewer:

проф. дтн. инж. Димитър Георгиев