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IMPLEMENTATION OF COVERING ALGORITHM FOR THE ROBOT WITH PARALLEL STRUCTURE

Abstract. The paper considers a 3RPR robot with a parallel structure. One of the main tasks in robotics is to determine the working area of the robot. Algorithms for solving systems of this type are given. The properties and accuracy estimates of the obtained approximations are proved. As an approach to determining the work area, the method of non-uniform coatings was used in this work, which allows one to determine the external and internal approximation of the set of solutions of the system with a given accuracy.

Keywords: parallel structure robot, non-uniform covering, work space, system of nonlinear inequalities.

Robots of a parallel structure are widely used due to a number of design advantages compared with serial mechanisms. For example, less load on the load-bearing elements and better positioning accuracy of the end-effector could be achieved. These robots are formed by a series of parallel kinematic chains connecting the base of the robot and the end-effector.

In this paper considered a parallel robot, having 3 degrees of freedom (figure 1). The given robot type has 3 link rods A_iB_i, which execute forward movements and B_iC, fulfilling two-dimensional motion [1].

For the given robot type the actuators coordinates are positions of B_i, that is, the link rods lengths A_iB_i. B_i, points, that are link roads of A_iB_i. Let's assume, that link rods lengths B_iCi =1,2,3 cannot be random and limited from above and below with some magnitudes l_{min}, l_{max}, with one and the same for all three rods depending on actuators. The C working organ position in the operational space is assigned with masses center coordinates (*x,y*) and platform tilting angleφin the plane *Oxy.* Let's denote through DB_iC link rod length, which is a constant value for the given robot, h_i height of lift point B_i from the *C* levelvia φ_i tilts A_iB_iC between the rod and B_iC and verticalbar A_iB.

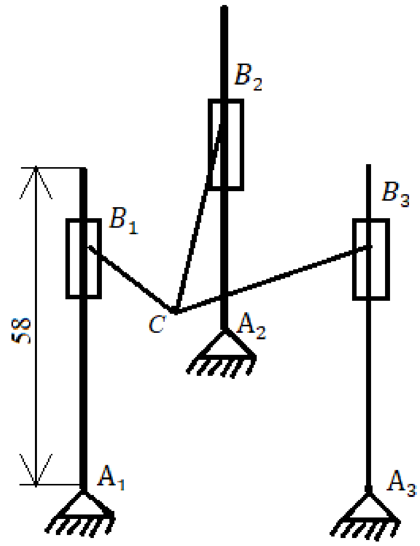

Figure 1 – Inematic diagram

Let's recordlimitations in the platform center coordinates, connected with the link rods lengths in the plane *Oxy*:

$$l_{min} \le |B_iC\sin\varphi_i| \le l_{max}, i = \overline{1,3},$$

or, in expanded form

$$(x - x_{Bi})^2 + (y - y_{Bi})^2 - l_{imax}^2 \le 0, \quad (1)$$
$$l_{imin}^2 - (x - x_{Bi})^2 - (y - y_{Bi})^2 \le 0,$$

$$i = \overline{1,3}.$$

hereby

$$l_i = D\,\sin\varphi_i,$$

$$\varphi_i = \arccos\frac{h_i}{D},$$

$$l_i = D\sin\left(\arccos\frac{h_i}{L}\right) = \sqrt{D^2 - h_i^2}, \qquad (2)$$

$$\left|\frac{h_i}{D}\right| < 1{,}0 < h_i < D.$$

As it can be seen, the limitations on the given robot have the same formas for the 3RPR type plain robot. It means, that the robot's kinematic diagramis given in the same diagram, which is similar to 3RPR robot, having been considered at the research's previous stages [2].

Numerical outcomes. As we see, at the fixed limitation actuators the heights (1) are assigned with circumference equations in the variables planes (*x,y*). Inourre search we applied anon-uniform coverings concept for constructing the robot's working area based on limitations, which were formed with six inequations (1) on variables (x,y) and limitation (2). In the below given examples we have assigned the fixed values of maximum and minimal height s$h_{max} = 21\ cm, 27\ cm, h_{min} = 7\ cm, 4\ cm$ and computed the possible limitations covering and internal working area. To take in to account the feasible allowances in the minimal and maximum link rods lengths possible values, we have included the allowance for the link rod length asε>0.

Non-uniform covering algorith m (figure 2) for the limitation case in the form of inequation might be formulated as [3, 4]:

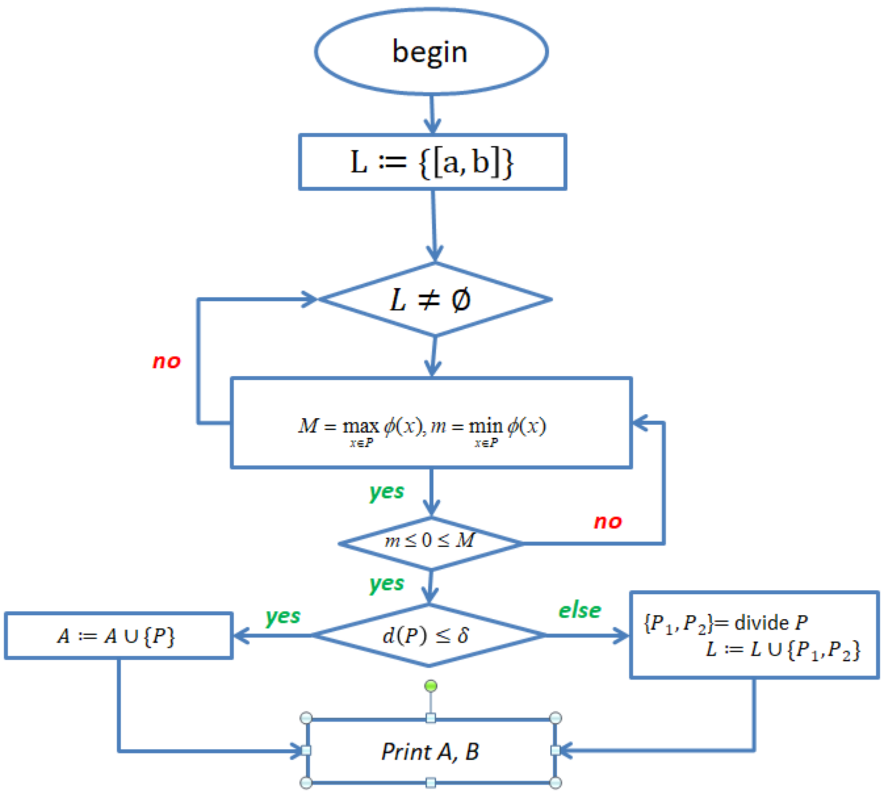

Figure 2 – Covering algorithm

Numerical modeling has been conducted for the following geometrical parameters of the robot: D =B_iC = 22 cm, A_iB_j≤ 58 cm, A_1A_2 = 28 cm.

Table 1 – Operating are a volume for specified actuators height

	$h_{max} = 21\ cm,$ $h_{min} = 7\ cm$	$h_{max} = 27\ cm,$ $h_{min} = 4\ cm$
S(cm^2)	57,81	9,38

Covering the working area and its borders are shown in figure 3 and 4.

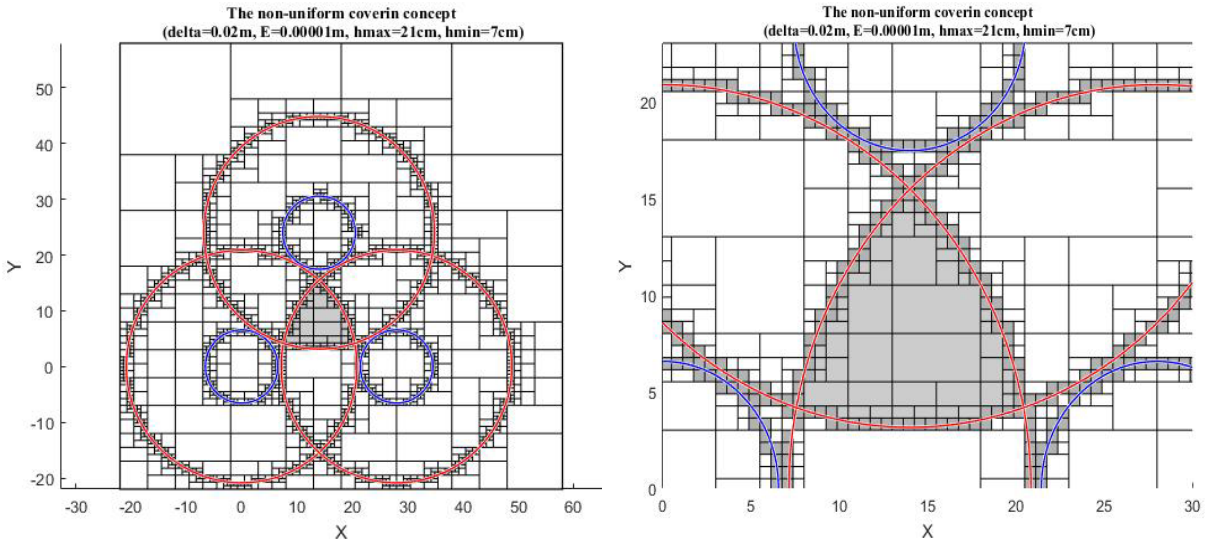

Figure 3 – Covering the working area and its borders, having been constructed
with the non-uniform covering concept at maximum and minimal height values$h_{max} = 21\ см, h_{min} = 7\ cm$.

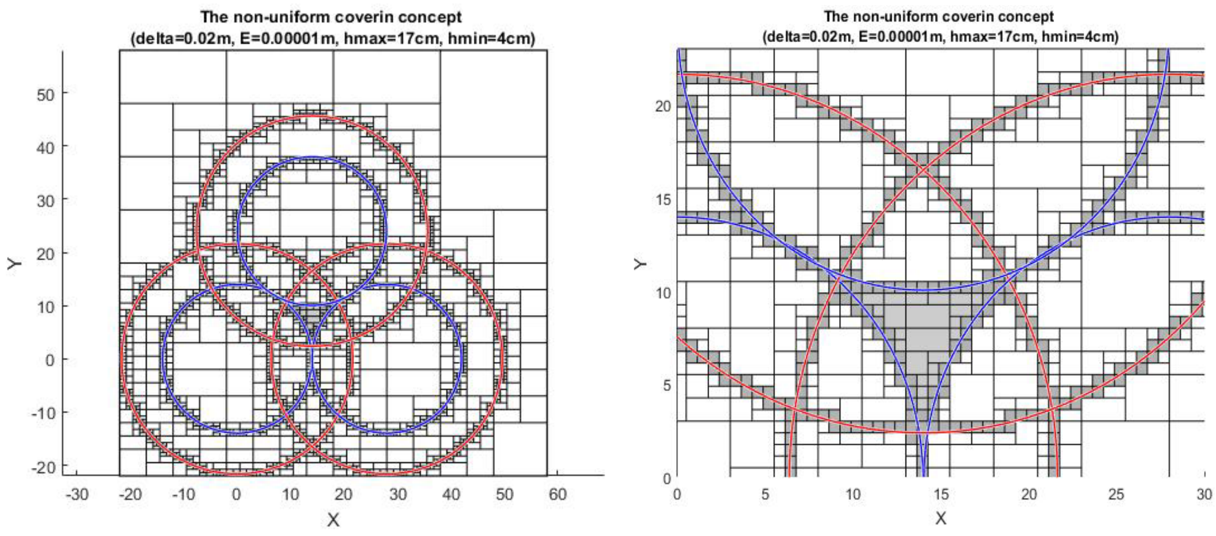

Figure 4 – Covering the working area and its borders, having been constructed
with a non-uniform covering concept at maximum and minimal height values $h_{max} = 27\ cm, h_{min} = 4\ cm$.

Computations have been done on the personal computer in the language C++, the outcomes visualization has been executed in Matlabs of t ware.

Table 2 – Amount of the rectangles, processed in the algorithm to prove the computations different accuracy and ε (figure 5)

δ/ ε (м)	0.02 / 0.0001	0.015/0.0001	0.01/0.0001	0.005/0.0001
Rectangles quantity in the working are a covering	48	72	112	245
Rectangles quantity in borders covering	988	1476	2006	3565
Rectangles quantity in processing	2483	3447	4883	9672

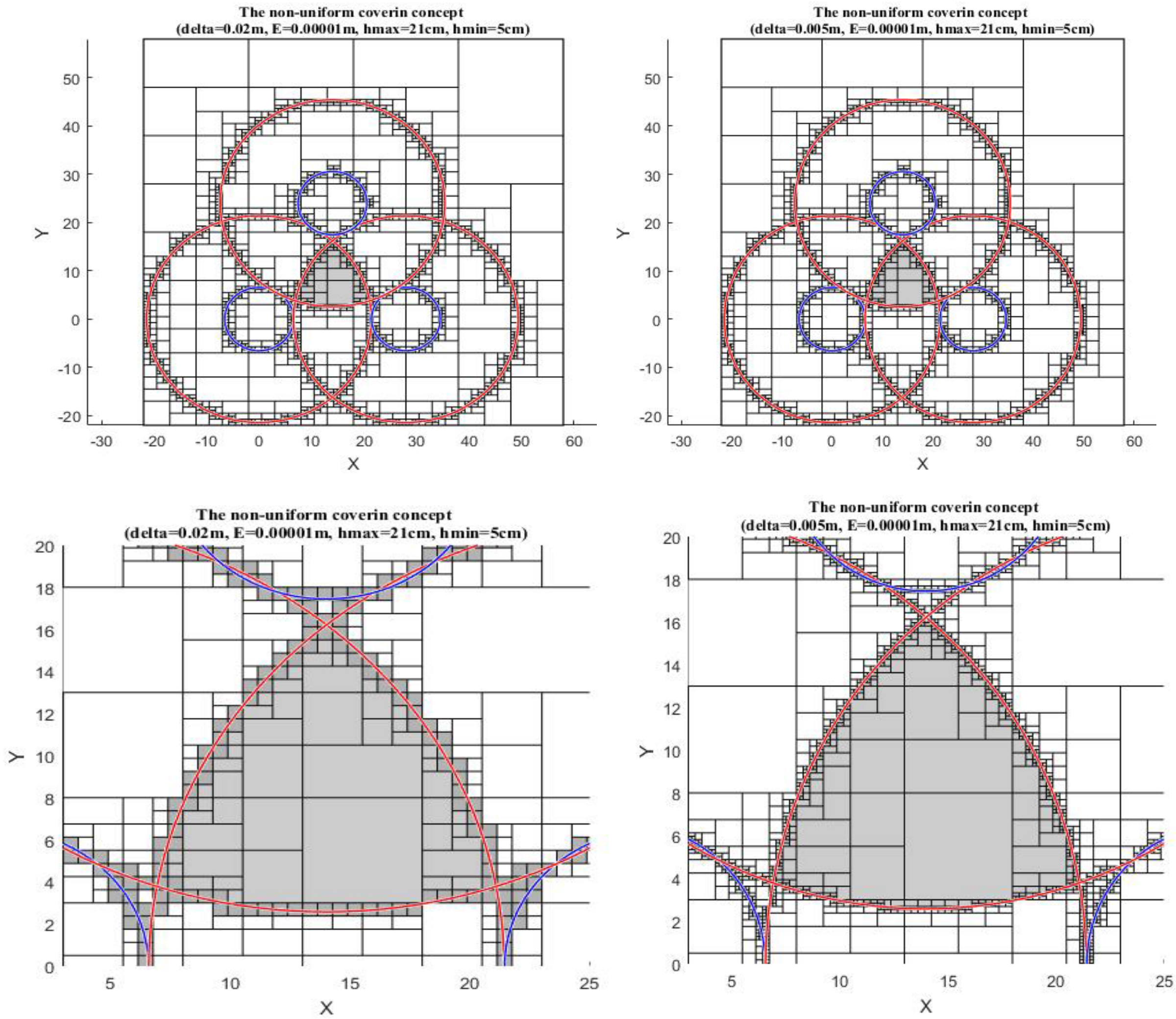

Figure 5 – Covering of the working area and its borders, having been constructed with the non- uniform covering concept for different computation accuracy

Conclusion. At this stage, a numerical implementation of the method of non-uniform coatings was performed for a number of model examples. Numerical calculations showed that the method of non-uniform covering can be applied to models of robots of parallel structure, in particular, for a flat robot with three degrees of freedom 3RPR. In the future, systematic calculations will be performed for different types of constraints and other types of robots. Covering of the working area and its borders, having been constructed with the non- uniform covering concept for different computation accuracy. To prove the computations different accuracy and ε amount of the rectangles, processed in the algorithm. The problem of approximating the solution set of a system of equalities or inequalities is considered. A practical example is given that can be formulated in one of these forms.

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РЕАЛИЗАЦИЯ АЛГОРИТМА ПОКРЫТИЯ ДЛЯ РОБОТА С ПАРАЛЛЕЛЬНОЙ СТРУКТУРОЙ

Аннотация. В статье рассматривается робот 3RPR с параллельной структурой. Одной из основных задач в робототехнике является определение рабочей зоны робота. Приведены алгоритмы решения систем этого типа. Доказаны свойства и оценки точности полученных приближений. В качестве подхода к опреде-

лению рабочей зоны в данной работе использовался метод неравномерных покрытий, который позволяет определить внешнюю и внутреннюю аппроксимацию множества решений системы с заданной точностью.

Ключевые слова: робот параллельной структуры, неравномерное покрытие, рабочаяобласть, система нелинейных неравенств.

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ПАРАЛЛЕЛЬ ҚҰРЫЛЫМЫ БАР РОБОТТЫҢ ҚАМТУ АЛГОРИТМІН ІСКЕ АСЫРУ

Аннотация. Мақалада параллель құрылымы бар 3RPR роботы қарастырылады. Робот техникасындағы негізгі міндеттердің бірі роботтың жұмыс аймағын анықтау болып табылады. Осы типтегі жүйелерді шешу алгоритмдері келтірілген. Алынған жуықтаулардың қасиеттері мен дәлдіктері дәлелденді. Осы жұмыста жұмыс аймағына нықтауға тәсіл ретінде біз жүйенің шешімдер жиынтығын берілген дәлдікпен сыртқы және ішкі жақындастыруды анықтауға мүмкіндік беретін бір келкі емес қамту әдісін қолдандық.

Түйін сөздер: параллель құрылым роботы, біркелкі емес қамту, жұмыс аймағы, сызықты емес теңсіздіктер жүйесі.

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