DETERMINING THE WORKSPACE SHAPE OF A ROBOT WITH DELTA 3D OF PARALLEL STRUCTURE

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Abstract: During the latest years, the robots that include mechanisms with Delta 3DOF parallel structure attracted the attention of the university research centers due to their unexploited potential. Besides the advantages given by the Delta 3DOF parallel structure, there is a series of disadvantages too. A significant disadvantage is the fact that the workspace is limited. Under these conditions, the studies on determining and improving the workspace got intensified lately. This work is presenting a study on determining the workspace of a parallel structure Delta 3DOF, by using a method that digitizes the angular position parameters of the active kinematical couplings.

Keywords: workspace, determining the workspace shape

1. INTRODUCTION

During the latest years, the robots that include mechanisms with parallel structure began to be used more and more, due to the potential of these structures. The robots that include mechanisms with parallel structure have numerous advantages compared to serial structures, as for instance: higher stiffness, transport of heavier objects, high accuracy. These advantages are also given by the fact that the mass of the handled object is taken over by each kinematical linkage apart [1, 2]. As far as disadvantages are concerned, a more significant one would consist of the fact that the workspace of the manipulators with parallel structure is smaller than the workspace of the serial structure manipulators [2]. Under these conditions, the researches on optimizing the parallel structure mechanisms of the industrial robots in terms of the workspace volume, intensified in the latest years.

This work is approaching the issue of determining the workspace shape of a robot with Delta 3DOF parallel structure (Figure 1). The parallel structure Delta 3DOF was patented in the beginning of the eighties by Professor Reymond Clavel [3].

The space positioning of the moving platform is performed through a certain combination of angles achieved by the leading elements 4 (Figure 1), driven by the driving system 1 (Figure 1), in relation to the plane, within each kinematical linkage apart.

The Delta parallel structure has three degrees of mobility, so it can perform three translations. The workspace for a robotic structure with three mobility degrees, of translation, consists of a volume that the handled object can traverse without changing its orientation [4].

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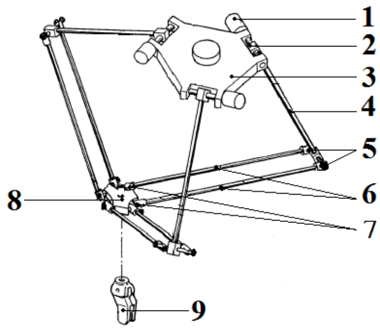

Fig. 1. Parallel Structure Delta [3]: 1— Driving system; 2— Kinematical rotary coupling; 3— Fixed platform; 4— Leading element; 5— Spherical kinematical couplings; 6— Leading elements; 7— Spherical kinematical couplings; 8— Moving platform; 9— handled object [3].

Along the years, the following categories of methods have been used for determining the workspace: geometrical methods, digitizing methods and numerical methods. In terms of determining the workspace through geometrical methods in case of the Delta 3DOF parallel structure, it can be done through a CAD program where the workspace is given by the intersection of three torus obtained further to the motions that each kinematical linkage can perform apart [5]. Almost all methods used for determining the borders of the workspace of the parallel structure robots are based on digitizing the position parameters. For determining the workspace through numerical manners, there are several methods in function of the type of the robot whose workspace needs to be determined. Jo D.Y. and Haug E.J. are using a method based on the Jacobian matrix [6] for determining the workspace. Another method frequently used by researchers for determining the workspace would be the Monte Carlo method [4].

2. FORMULATING THE METHOD USED FOR DETERMINING THE WORKSPACE

For determining the workspace of the Delta 3DOF parallel structure this work made use of a method that digitizes the variation intervals of the articulated coordinates of the active kinematical couplings, whose solution is numerical. The method requires the usage of the direct geometrical pattern of the Delta 3DOF parallel structure. In case of the direct geometrical pattern the articulated coordinates are known and the coordinates of the handled object are required. For determining the experimental results, the direct geometrical pattern approached by Luc R. in the work [7] has been used.

The geometrical diagram as well as the representation of the geometrical parameters used within the Delta 3DOF parallel structure may be seen in Figure 2 and Table 1 below.

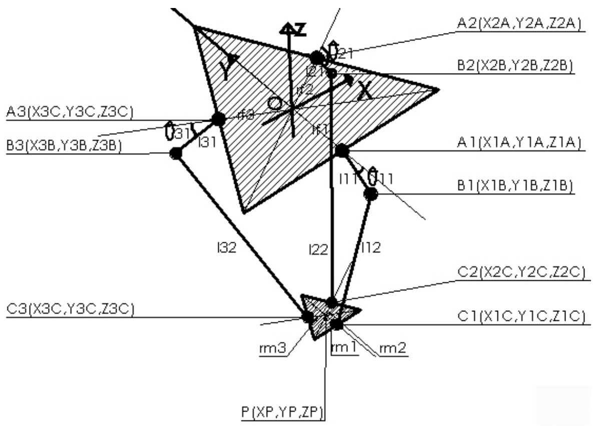

Fig. 2. Geometric diagram of the Delta 3DOF parallel structure.

The three kinematical linkages of the structure are located at an angle of 120^0 to each other. The geometrical parameters used in this structure are presented in Table 1 below:

Table 1. Geometrical Parameters.

Geometrical Parameters	rf_1, rf_2, rf_3 - radius of the fixed platform l_{11}, l_{21}, l_{31} - length of the leading element l_{12}, l_{22}, l_{32} - length of the idle element rm_1, rm_2, rm_3 - radius of the moving platform θ_{11}, θ_{21}, θ_{31} .- articulated coordinates

The block diagram based on which the workspace will be determined is shown in Figure 3.

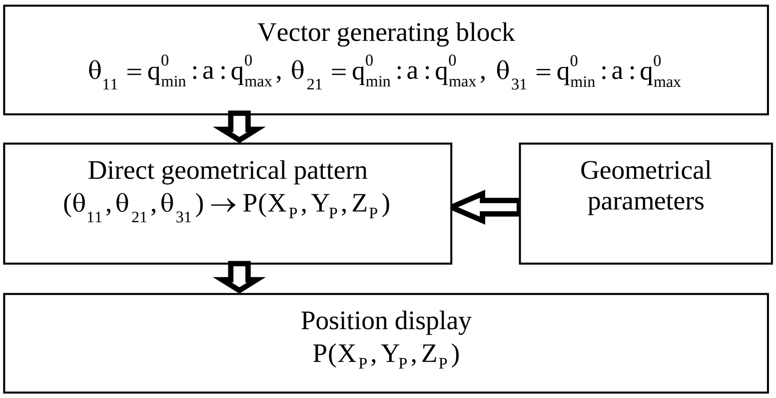

Fig. 3. Block diagram of the method used for determining the workspace.

The workspace is determined as per the block diagram, by performing the following steps:
Step 1. With the help of the vector generating block all possible combinations of the values of the angles θ_{11}, θ_{21}, θ_{31}, will be generated in the interval $q^0_{min}...q^0_{max}$, interval being digitized through an digitizing increment *a*. The interval $q^0_{min}...q^0_{max}$ is given by the mechanical limits of the kinematical rotary couplings or by the limits given by the driving devices.

Step 2. Based on the angular positions generated by using the direct geometrical pattern the position of the handled object will be calculated apart for each combination of angles θ_{11}, θ_{21}, θ_{31}. The maximum number of points being generated may be emphasized through the relation 1 below:

$$N_p = \left(\frac{u^0}{a} \right)^3 \tag{1}$$

where: N_p - number of points generated inside the workspace; u^0 - maximum moving angle of the leading elements l_{11}, l_{21}, l_{31}; a – digitizing increment in the interval of the articulated coordinates $q^0_{min}...q^0_{max}$.

Step 3. The Cartesian coordinates obtained further to applying the direct geometrical pattern will be displayed. The shape of the workspace will be given by the totality of the Cartesian coordinates represented within the structure.

3. EXPERIMENTAL RESULTS

For simulating the workspace a Delta parallel structure has been proposed, having the characteristics stated in Table 2. The digitizing increment *a* that was used, is 2. With the help of the vector generating block the possible combinations of angles for θ_{11}, θ_{21}, θ_{31} have been generated, whose values are included to the intervals: 0^0 - 90^0, $\theta_{11} = 0^0 : 2 : 90^0$, $\theta_{21} = 0^0 : 2 : 90^0$, $\theta_{31} = 0^0 : 2 : 90^0$, thus generating the points of inside the workspace.

Table 2. Dimensions and constructive restrictions of the Delta 3DOF parallel structure.

Constructive dimensions	Values of the constructive dimensions
$rf_1 = rf_2 = rf_3$	170
$rm_1 = rm_2 = rm_3$	70
$l_{11} = l_{12} = l_{13}$	40
$l_{21} = l_{22} = l_{23}$	150
$\theta_{11max} = \theta_{12max} = \theta_{13max}$	90^0
$\theta_{11min} = \theta_{12min} = \theta_{13min}$	0^0

As such, 91125 points of the handled object inside the workspace have been generated. Further to the implementation of the Matlab method, the workspace of the Delta 3 DOF parallel structure has been obtained, as shown in Figure 4 and Figure 5 below:

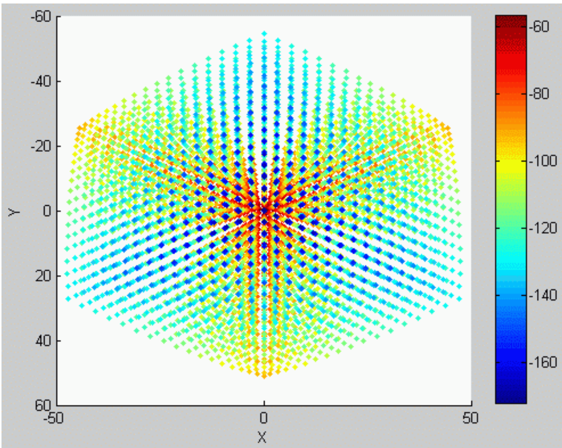

Fig. 4. Workspace simulation, view in the YX plane.

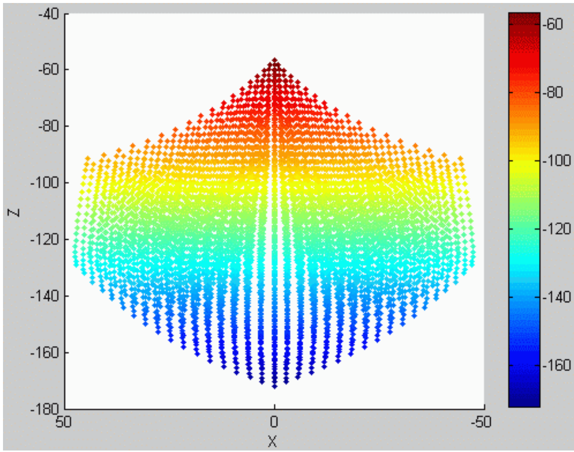

Fig. 5. Workspace simulation, view in the ZX plane.

4. CONCLUSIONS

It may be concluded that this method may be used for determining the workspace, by presenting a simple algorithm. By digitizing the interval $q^0_{min} ... q^0_{max}$ through a digitizing increment *a* as small as possible, more precise determinations of the workspace may be done. The workspace shape differs in function of the constructive dimensions of the structure. A disadvantage of this method would consist of the fact that the volume of the workspace cannot be very easily determined. A method that allows determining the workspace volume as well would be the Monte Carlo method.

Within this method only the restrictions in the active kinematical coupling have been considered; for a more precise determination of the workspace the restrictions of the elements of the passive kinematical couplings may be also considered.

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