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CAD MODEL OF THE RTTRR MODULAR SMALL-SIZED SERIAL ROBOT

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Abstract: *the paper presents the CAD model of the RTTRR-type modular small-sized serial robot. After a short description of the rotation and translation modules from the mechanical structure of modular small-sized robots, the concept of modularity is applied on the design of the RTTRR-type small-sized robot, which can be used in a variety of technological processes, such as: manipulation, assembly, sorting, packaging, quality control and testing.*
Key words: *modular robot, CAD model, small-sized robot.*

1. INTRODUCTION

The specialized industrial small-sized robots rise the problem of building a large constructive range of robots, starting from the simple robots, with low flexibility, to the smart robots, with controlled multiple interactions with the environment. One of the mechanical solutions to this problem is the robot modularity approach [1]. This concept implies the production of a certain number of standard modules which combined differently and efficiently, lead to a variety of models, different in complexity and application fields.

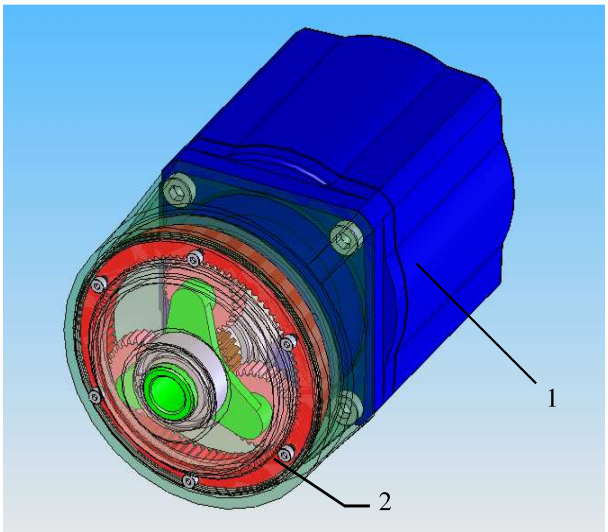

Fig. 1 The structure of the rotation module

The building of industrial small-sized robots, regardless of their applicability domain, has to respond to functional requirements of the technological process they are implemented in, ensuring a proper workspace to the operation they have to execute, in given kinematic and dynamic conditions and assuming a high reliability. These requirements imply achieving of translation and rotation modules which make use, instead of sliding friction, the rolling friction, ensuring, along with friction forces considerably lower, a better dynamic response of the robot mechanical structure [2].

2. ASPECTS REGARDING THE BUILDING OF ROTATION MODULES

The rotation modules from the mechanical structure of the small-sized robots ensure the rotation motion about a fixed axis (joint axis), of certain robot's parts. The rotation modules have in their structure, generally, actuation elements (usually electric motors, DC or stepper), motion transmission elements (speed reducers, gears, balls or roller screws, belts, flexible wires) and connection parts (flanges, screws, rods etc.) [3].

The direct drive modules are a special case in the building of rotation modules. The essential peculiarity is their direct connection to the actuator axis, without the need of a speed reducer, gears or other motion transmission elements.

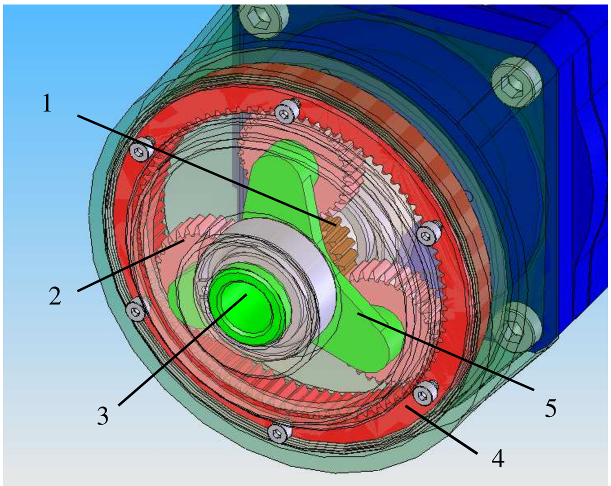

Fig. 2 Planetary speed reducer

The rotation module presented in fig. 1 is the standard rotation module from the structure of RTTRR small-sized robot. The main component is the drive/speed reducer assembly, consisting in a DC motor (1) and a planetary speed reducer (2).

The planetary speed reducer from fig. 2 has the input pinion (1) connected to the DC motor shaft, three identical satellite gears (2), which are located between the pinion (1) and the inner toothed crown (4). The satellite gears transmit the rotation motion to the solar arm (5), connected to the output shaft (3) of the speed reducer.

3. ASPECTS REGARDING THE BUILDING OF TRANSLATION MODULES

The translation modules from the small-sized robots mechanical structure are required to ensure the relative linear motion of the robot's parts. Fig. 3 presents the standard translation module used in the structure of RTTRR small-sized robot and this also could be used in the building of other small-sized robots [4], [5], [6].

The basic principle of the translation module operation is the conversion of the rotation motion given by the drive/speed reducer assembly (1) into linear motion, by means of a ball screw (4), fixed with bearings to its ends. The screw rotation motion is transmitted to the sled (3) which contains the nut (6) and the rolling guides (5), which lead the sled on the two longitudinal columns (2). The CAD model of a rolling guide is presented in fig. 4.

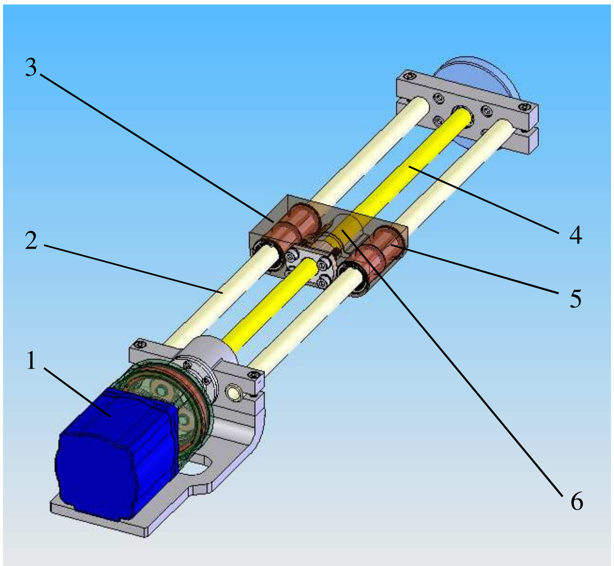

Fig. 3 Translation module structure

4. THE MECHANICAL STRUCTURE OF RTTRR SMALL-SIZED ROBOT

Combining the above described rotation and translation modules in an adequate way, according to the requirements of the technological process to be implemented in, different particular robot structures may result. One of them is the RTTRR-type robot (fig. 5), a modular small-size robot with five degrees of freedom. There are in its structure: the support (1) of the robot's base, the rotation module (2) of the robot arm, having a vertical rotation axis and a generalized coordinate q_1. The translation vertical module (3) is attached to it, having the generalized coordinate q_2. The sled of the module (3) is attached to the sled of the next translation module (4), which makes a horizontal linear displacement, with the generalized coordinate q_3, having the function

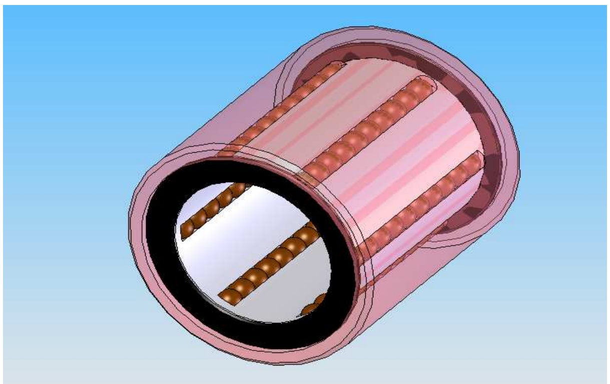

Fig. 4 Rolling guide

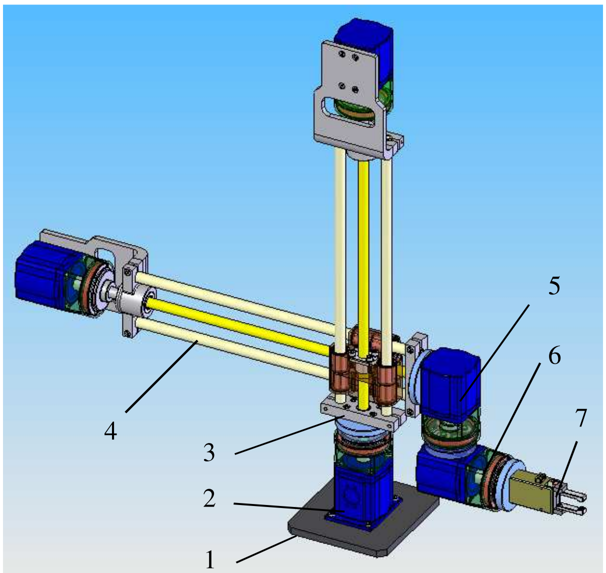

Fig. 5 RTTRR small-sized robot, zero-configuration

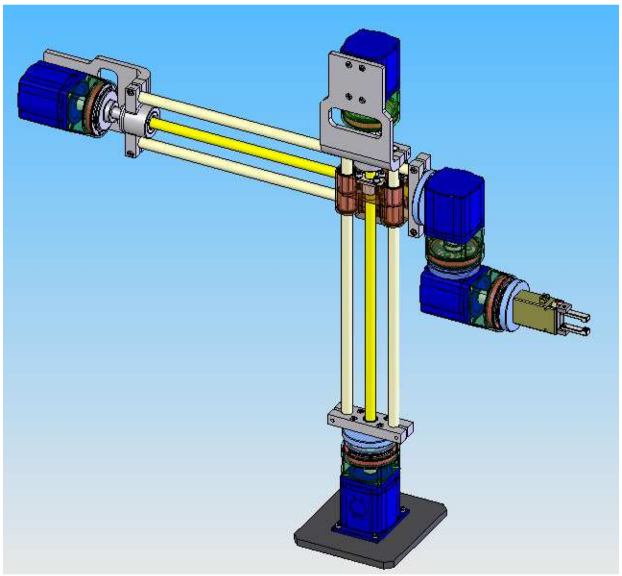
Fig. 6 RTTRR small-sized robot, q_{2max} displacement

of extending / withdrawal of the robot arm. At the end of the module (4) there is the orientation module of the gripper, having two degrees of freedom, consisting in the rotation module (5), which performs a rotation with respect to a vertical axis, with the angle q_4, and the rotation module (6), executing the gripper (7) orientation, about its symmetry axis, with the angle q_5. Situated at the end of the open kinematic chain of the serial modular small-sized robot, the gripper (7), designed to perform simple manipulation tasks, has two straight fingers which close the gripper by a reciprocal translation motion, ensuring the grasping of the manipulated object. According to the robot's task and to the necessary technological operation, the gripper can be replaced by another type of end-effecter, such as: multi-fingered gripper, painting pistol, welding head, rotary machine tools etc.

Some particular robot configurations are described as follow, each of them presenting the maximum strokes in the translation modules and some particular robot positions obtained by the angular displacements in the rotation joints.

Fig. 5 presents the robot into the conventionally chosen zero-configuration, i.e. zero value of the generalized coordinates q_i, $i = \overline{1,5}$. Fig. 6 specifies the maximum displacement in the vertical translation joint, q_{2max}, ensuring the lifting of the robot arm into the upper position.

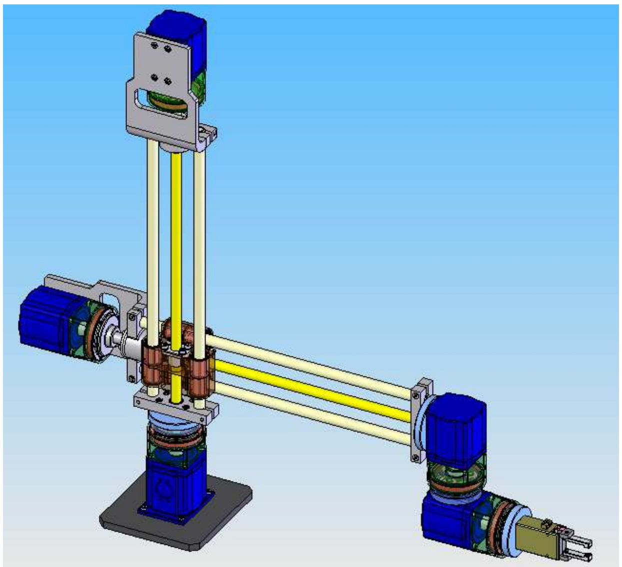
Fig. 7 RTTRR small-sized robot, q_{3max} displacement

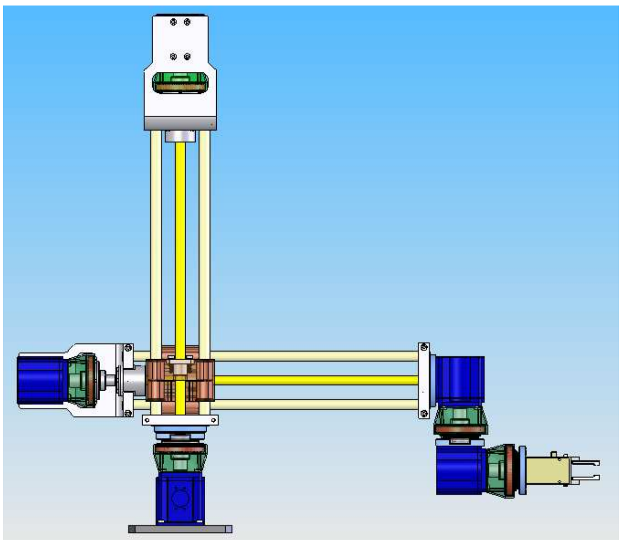
Fig. 8 RTTRR small-sized robot, q_{3max} displacement, front view

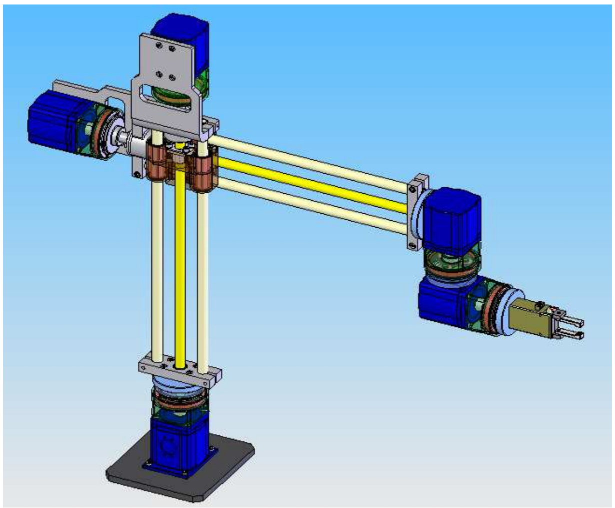

Fig. 9 RTTRR small-sized robot, q_{2max}, q_{3max} displacement

Fig. 7 and 8 present in two different views (trimetric view and front view) the maximum displacement in the horizontal translation joint, obtaining the extreme (q_{3max}) position from the lower horizontal plane of the gripper and the maximum operation radius (the reach) of the robot arm. Fig. 9 combines the maximum displacement in the two translation joints, q_{2max} and q_{3max}, giving the extreme end-effecter position in the upper horizontal plane. In fig. 10 and fig. 11, keeping the maximum strokes in the translation joints, the whole robot assembly is rotated from the base rotation joint with q_1=90° and q_1=180°.

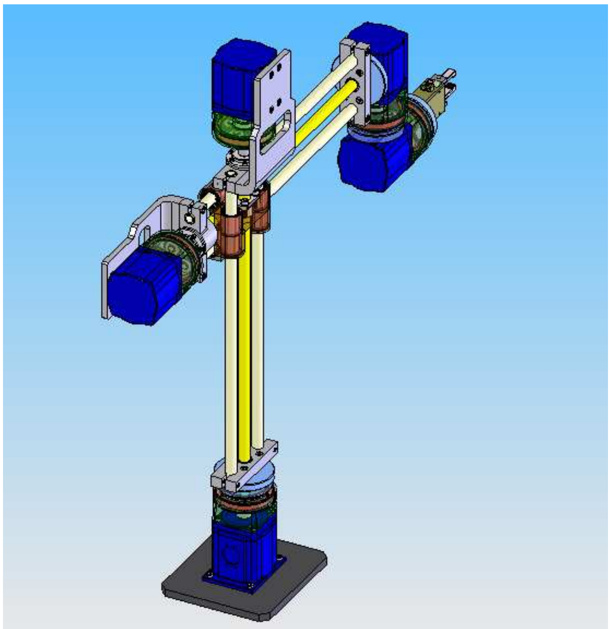

Fig. 10 RTTRR small-sized robot, q_1 = 90°, q_{2max}, q_{3max} displacement

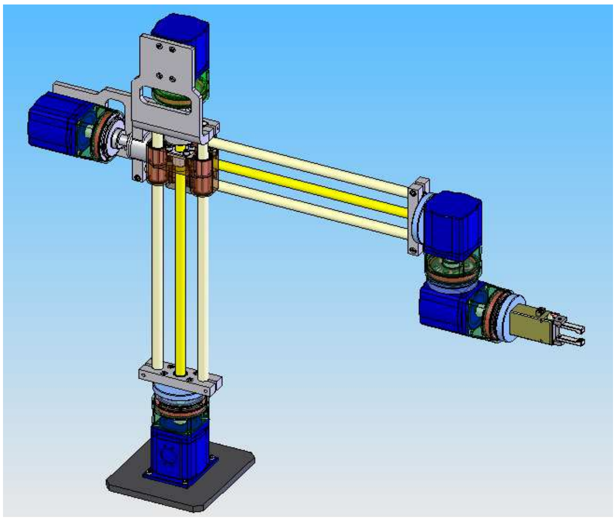

Fig. 11 RTTRR small-sized robot, q_1 = 180°, q_{2max}, q_{3max} displacement

From the last configuration, the gripper is rotated with q_4=180° (fig. 12), being therefore oriented towards the vertical translation axis.

Fig. 13 presents, eventually, the horizontal orientation of the gripper by the angular displacement with q_5=90° of the last rotation joint of the orientation mechanism. The equivalent kinematic diagram of the robot is presented in fig. 14. The constructive dimensions, as resulted from the CAD model, are:

$$\begin{array}{ll} l_0 = 135.50 \text{ mm}; & l_1 = 72 \text{ mm}; \\ l_2 = 32 \text{ mm}; & l_3 = 0 \text{ mm}; \\ l_4 = 111.50 \text{ mm}; & l_5 = 130 \text{ mm}; \\ l_6 = 148.60 \text{ mm}. & \end{array} \tag{1}$$

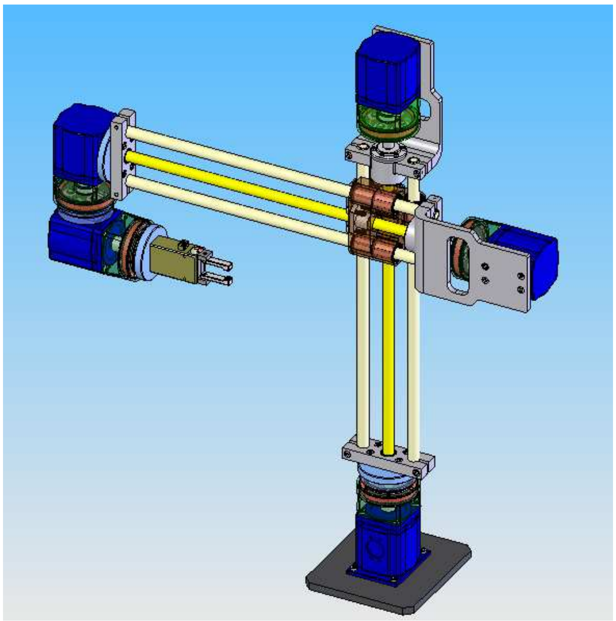

Fig. 12 RTTRR small-sized robot, q_1 = 180°, q_{2max}, q_{3max}, q_4 = 180° displacement

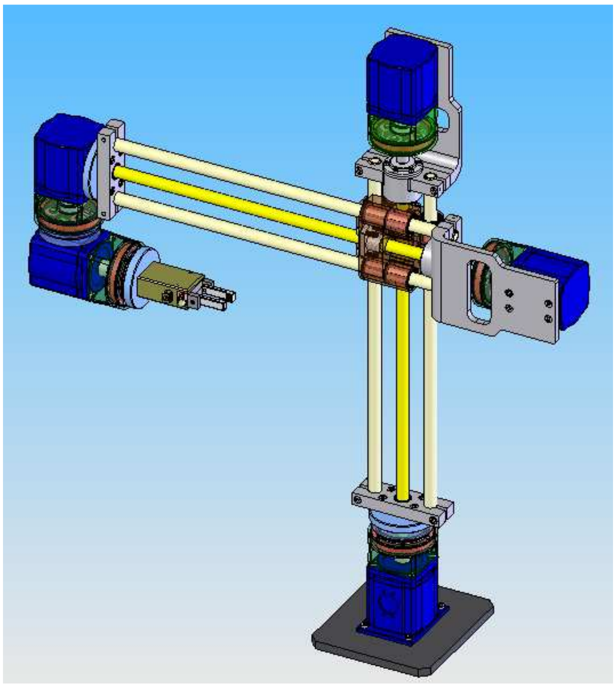

Fig. 13 RTTRR small-sized robot, $q_1 = 180°$, q_{2max}, q_{3max}, $q_4 = 180°$, $q_5 = 90°$ displacement

The masses of the modules, after setting the proper density of the component materials, are the following:

$$M_1 = 11.30707 \text{ kg}; \quad M_2 = 1.95559 \text{ kg}$$
$$M_3 = 8.16752 \text{ kg}; M_4 = 3.2593 \text{ kg} \qquad (2)$$
$$M_5 = 1.44660 \text{ kg}.$$

The mass centers are characterized by the following position vectors, having the components in mm:

$$^1r_{C_1} = \begin{bmatrix} 1.15 \\ 0.00 \\ 297.24 \end{bmatrix}; \; ^2r_{C_2} = \begin{bmatrix} -16.00 \\ 1.47 \\ 371.68 \end{bmatrix}; \; ^3r_{C_3} = \begin{bmatrix} -1.46 \\ 107.00 \\ -0.50 \end{bmatrix}$$
$$^4r_{C_4} = \begin{bmatrix} 0.00 \\ 0.00 \\ -17.50 \end{bmatrix}; \; ^5r_{C_5} = \begin{bmatrix} 0.00 \\ 55.12 \\ 0.00 \end{bmatrix}. \qquad (3)$$

4. CONCLUSIONS

The obtained CAD model is useful in the study of the possible implementations of the RTTRR small-sized robot. Using this model, the shape and volume of the robot workspace can be analyzed, leading to the conclusion that this robot can be used in certain technological processes.

The obtained geometric dimensions, together with the mass distribution elements (masses, mass centers and moments of inertia), taken from the CAD model properties, are useful in the numeric simulation of the kinematic and dynamic behavior of the RTTRR small-sized robot [7], [8], [9], [10].

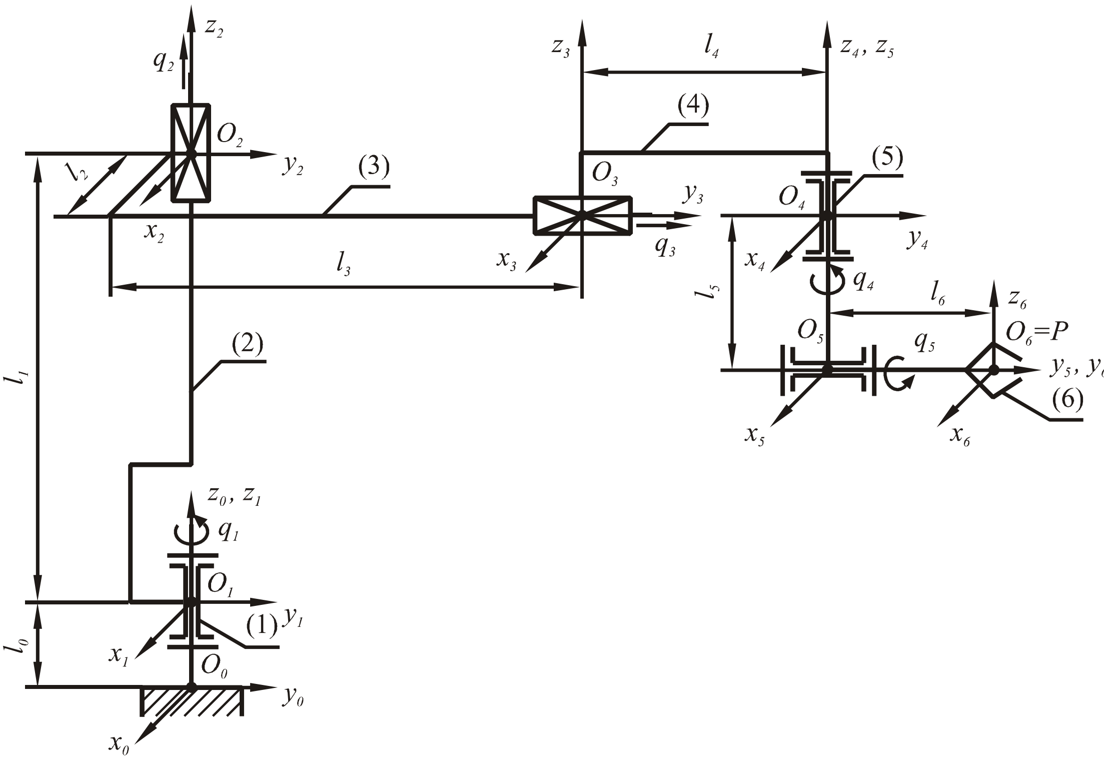

Fig. 14 The kinematic diagram of the RTTRR small-sized robot

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Modelul CAD al minirobotului serial modular RTTRR

Rezumat: Lucrarea prezintă modelul CAD al minirobotului serial modular de tip RTTRR. După o scurtă descriere a modulelor de rotaţie şi translaţie din structura mecanică a miniroboţilor modulari, în proiectarea minirobotului RTTRR este aplicat conceptul de modularitate, robotul rezultat putând fi implementat într-o varietate de procese tehnologice, cum ar fi: procese de manipulare, asamblare, montaj, sortare, ambalare, testare şi control al calităţii.

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