UDC: 531.323.2

M. O. Chernilevskyi[1]
K. I. Yanchuk[1]
R. S. Belzetskyi [1]

METHODS FOR SOLVING THE DIRECT KINEMATICS PROBLEM FOR DETERMINING THE GRIP POSITION OF THE ROBOT-MANIPULATOR IN SPACE

[1] Vinnytsia National Technical University

Анотація

У статті представлено різні кінематичні параметри, що використовуються для опису руху маніпулятора. Наведено методи розв'язання прямої задачі кінематики на прикладі маніпуляторів з поступальними та обертальними ступенями рухливості.

Ключові слова: робот-маніпулятор, пряма задача кінематики, системи координат маніпулятора.

Abstract

The article presents various kinematic parameters used to describe the motion of the manipulator. The methods of solving the direct problem of kinematics are presented using the example of manipulators with translational and rotational degrees of mobility.

Keywords: manipulator robot, direct kinematics problem, manipulator coordinate systems.

Introduction

The design of manipulator robots [1] requires solving the following basic kinematics tasks:

- the direct task consists in determining the position and orientation of the grip, and if necessary, other links according to the given coordinates;

- the inverse task consists in determining the relative coordinates of the manipulator links based on the specified positions of the object or the grip rigidly connected to it;

A direct problem is usually used repeatedly when designing a manipulator. With its help, you can determine the characteristics of the working area of the manipulator with a complex kinematic scheme in the presence of restrictions on generalized coordinates, determine the accuracy of the characteristics, for example, errors in the position and orientation of the grip, which are caused by inaccurate manufacturing of the manipulator links, wear of parts, backlash, etc.

Main part

There are many methods of solving the listed tasks, which have their own advantages and disadvantages. The choice of one or another method is usually related to the specifics of the problem to be solved, as well as the features of the manipulator design.

The combination and mutual arrangement of links and connections determines the number of degrees of mobility, as well as the scope of the robot-manipulator system. As a rule, the first three connections in the executive mechanism of the manipulator implement the transport degrees of mobility of the manipulator robot, and the rest implement the orientational degrees of mobility of the grip in space [2]. Depending on the type of the first three connections, most robots fall into one of four categories:- robots working in the Cartesian coordinate system, in which all three initial connections are translational (see Figure 1.);

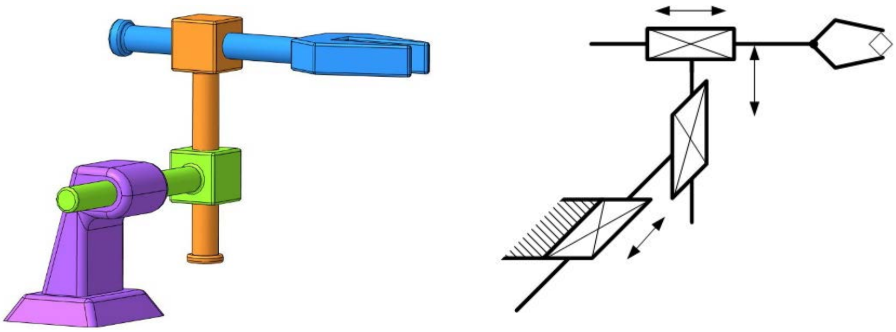

Figure 1 – Structural and kinematic diagrams and its 3D model of a manipulator robot with a Cartesian coordinate system.

- robots working in a cylindrical coordinate system, in which two translational and one rotational connections are among the initial connections (see Figure 2);

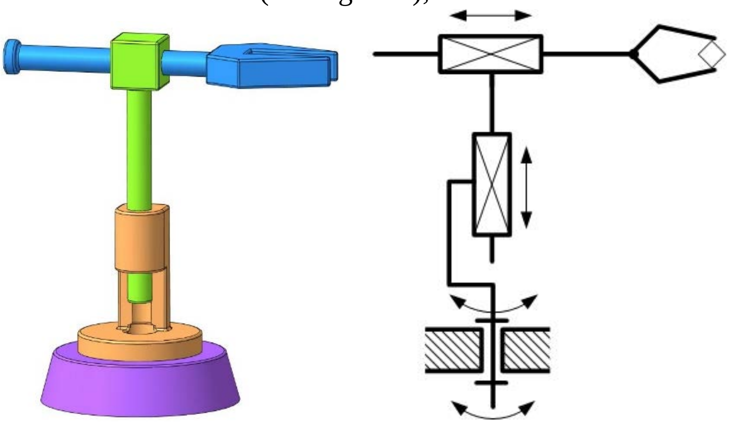

Figure 2 – Structural and kinematic diagrams and its 3D model of a manipulator robot with a cylindrical coordinate system.

- robots working in a spherical coordinate system, in which one translational and two rotational connections are among the initial connections (see Figure 3.);

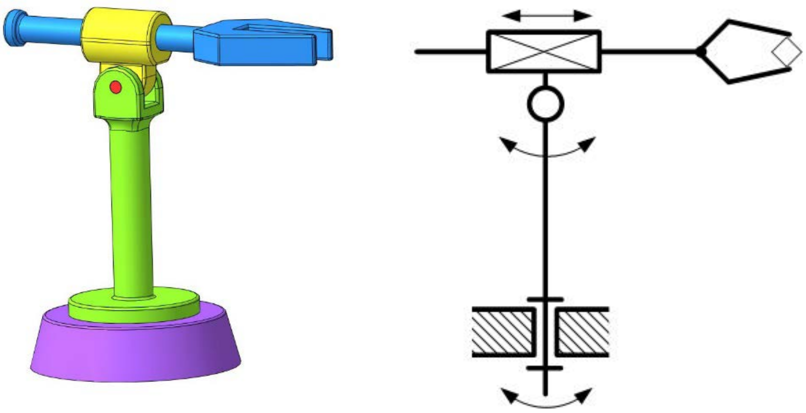

Figure 3 – Structural and kinematic diagrams and its 3D model of a manipulator robot with a spherical coordinate system.

- robots working in an angular or rotational coordinate system, in which all three initial connections are rotational (see Figure 4.).

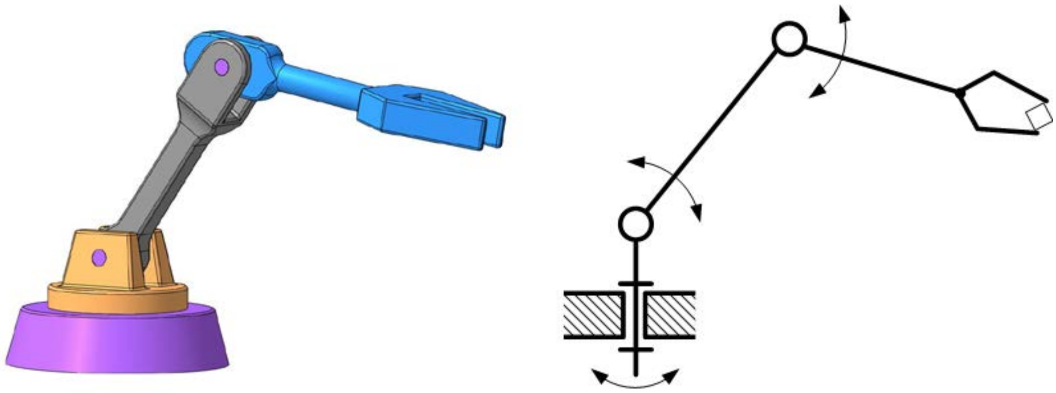

Figure 4 – Structural and kinematic diagrams and its 3D model of a manipulator robot with an angular coordinate system.

The direct problem of the position of the manipulator is one of the main problems of kinematics, which consists in calculating the position and orientation of the grip in space, based on given movements in separate kinematic pairs,

$$q_i(i = \overline{1,n});\ r_j(j = \overline{1,m}), m \le 6, \quad (1)$$

where q_i- generalized coordinates (angles of turns of links and/or movement), n - n - number of degrees of freedom, r_j- grip coordinates.

As a result of solving the direct problem, the position and orientation of the grip relative to the basic coordinate system are determined.

Conventionally, all methods of solving a direct problem can be divided into three groups:

1. Methods that make it possible to record the required ratios directly from the kinematic diagram of the manipulator, without using special techniques.

2. Methods based on the use of a matrix apparatus, for example, 4×4 uniform coordinate transformation matrices. This method uses coordinate systems attached to each moving link, as well as reference systems associated with the base. Transition matrices from one coordinate system to the nearest (adjacent) coordinate system are created. Then, all the resulting transition matrices are multiplied to create a resulting matrix that connects the base coordinate system to the coordinate system of any link, for example, a gripper.

3 Methods based on the use of the concept of a vector of finite rotation or a screw of finite displacement.

Conclusions

In the work, an overview of the coordinate systems of manipulator robots was carried out, structural and kinematic diagrams and its 3D model were given. An overview of the methods of solving the direct problem of kinematics was carried out on the example of manipulators with translational and rotational degrees of mobility.

REFERENCES

1. Белзецький Р. С. Чотирьохосьова рука-маніпулятор з тактильним зворотнім зв'язком [Електронний ресурс] / Р. С. Белзецький // Матеріали «XLVIII Науково-технічна конференція підрозділів Вінницького національного технічного університету», Вінниця, 2019. [Електронний ресурс]. Режим доступу: https://conferences.vntu.edu.ua/public/files/1/ininv_2019_netpub.pdf.

2. Ігнатишин М. І. Розв'язок зворотної задачі плоского маніпулятора в системі mathcad [Електронний ресурс] / М. І. Ігнатишин, В. І. Хімич // Мукачівський державний університет. – 2016. – Режим доступу до ресурсу: http://dspaces.msu.edu.ua:8080/bitstream/123456789/1292/1/%D0%86%D0%B3%D0%BD%D0%B0%D1%82%D0%B8%D1%88%D0%B8%D0%BD%20%D0%9C.%20%D0%86.%20%2813%29.pdf.

3. Вігуро М. І. Проектування промислових роботів та маніпуляторів [Електронний ресурс] / М. І. Вігуро, А. В. Маляр // Електроенергетичні та електромеханічні системи. – 2021. – Режим доступу до ресурсу: https://ena.lpnu.ua:8443/server/api/core/bitstreams/550f4ce4-a626-473c-99c0-5a8baab5999d/content.

Чернілевський Максим Олегович – студент групи 4кн-23б, кафедра комп'ютерних наук, факультет інтелектуальних інформаційних технологій та автоматизації, Вінницький національний технічний університет, м. Вінниця, e-mail: chernilevskiymo13@gmail.com

Янчук Костянтин Іванович – студент групи 4кн-23б, кафедра комп'ютерних наук, факультет інтелектуальних інформаційних технологій та автоматизації, Вінницький національний технічний університет, м. Вінниця, e-mail: leok7200@gmail.com

Белзецький Руслан Станіславович – канд. техн. наук, доцент, доцент кафедри комп'ютерних наук, Вінницький національний технічний університет, e-mail: belzetskiy@vntu.edu.ua.

Chernilevskyi Maxym O. — student of group 4kn-23b, Department of Computer Sciences, Faculty of Intelligent Information Technologies and Automation, Vinnytsia National Technical University, Vinnytsia, e-mail: chernilevskiymo13@gmail.com

Yanchuk Kostyantyn I. - student of group 4kn-23b, Department of Computer Sciences, Faculty of Intelligent Information Technologies and Automation, Vinnytsia National Technical University, Vinnytsia, e-mail: leok7200@gmail.com

Belsetskyi Ruslan S. — PhD (Eng.), Assosiate Professor of Department for Computer Science, Vinnytsia National Technical University, Vinnytsia, belzetskiy@vntu.edu.ua.