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*Odessa National Academy  
of Food Technologies*



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**BLACK SEA SCIENCE 2020**

Information Technology, Automation and Robotics

Proceedings

Odessa, ONAFT 2020

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twentieth century have described an era where the main function of man is to manage robots and artificial intelligence. All this is promised by Industry 4.0 today.

Take, for example, any factory / production that fits into the 4.0 model:

\*\* All operations of this factory are automated;

\*\* Introduced auto-monitoring system;

\*\* Machines / installations are fully computer driven;

\*\* Computers can learn, analyze situations, and make optimal, independent decisions for the enterprise.

Therefore, any business is in charge of keeping an eye on innovations in its field, timely implementing these innovations, developing a new model of competitiveness, and adapting timely to these changes.

Modern technology makes it easy, fast, efficient, secure, tailor-made, inexpensive, and so on. If you used to spend a lot of time, energy, money, and now in just a few seconds you can send information anywhere ... And electronic signatures can be said to be one of the great achievements of modernity when you can handle anything without leaving the room, with a range of security measures with protection.

## **THE USE OF SUPERVISED LEARNING IN ROBOTICS**

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***Abstract.** In this paper, there are considered definitions of the direct and inverse kinematics. The solution of inverse kinematics problem is shown in detail on the example of the kinematic scheme of the manipulator. Also, it is discovered the concept of degrees of freedom and coordinate system.*

*The example of path-planning shows the process of moving the robot along a curved path, determining the angle and distance that robot needs to go to the next point of the path.*

*Machine learning is also considered to be a unit of artificial intelligence. Classification and regression are found to be the main tasks of supervised learning. There were analyzed cases in which regression or classification are applied and were given examples of application of machine learning in the modern world and robotics.*

*This science paper contains 15 pages and 4 figures.*

***Keywords:** Inverse Kinematics Problem, Manipulator, Path-Planning, Machine Learning, Classification, Regression.*

### **I. Introduction**

Nowadays the need of using robots is growing more and more in various spheres of human life. The use of machine learning in robotics extends their application, facilitates human labor, and is highly efficient through the handling with the large amounts of data,

which is difficult enough for humans and sometimes even is impossible. All this contributes to further prospects in this direction.

That is why the science paper related to machine learning and robotics is now relevant and will gain further interest from both professionals and users. The purpose of my work is to study the kinematics of robots, to solve the inverse kinematics problem, to get acquainted with machine learning and the problems that are solved with the help of supervised learning and the practical application of machine learning.

This science paper considers the kinematics of the manipulator and the basic concepts used in its work and machine learning, solving some problems of supervised learning, the use of machine learning in robotics.

## **II. Analytical literature survey**

In [1] there were examined the formulation and solution of direct and inverse kinematics problems, revealed the importance of solving the inverse kinematics problem, explained the presence of ambiguity in its resolution.

Thus, in [2] there were discussed such basic concepts as the coordinate system, the degrees of freedom. Also this article showed the process of path-planning of the robot.

Using [5] there were found out the possibilities of using robots with machine learning, their limitations in comparison with the human being and given the examples of using of supervised learning in the modern world.

With the help of [6], theoretical information on supervised learning, differences between regression and classification were introduced.

The studying [7] examines the work of Google's laboratory on the application of machine learning to robotics, the prospects for their further development and the problems encountered by specialists.

## **III. The object, subject and research methods**

The research object is a mobile robot.

The research subject is the application of inverse problem solution of kinematics in robotics with using machine learning.

This paper uses a method of theoretical research as analysis and synthesis, since we first consider the individual parts of the subject of study, its properties, and then combine these parts to a single whole.

## **IV. Results**

### **IV.I Definition of direct and inverse kinematics problems**

In general robotics considers the solution of direct and inverse kinematics problems depending on the information about the motion of a point. Let us find out the differences between them by the example of the kinematic scheme of the two-link manipulator (fig. 1).

The direct task of kinematics is to find the position of the manipulator ( $X, Y, Z$ ) according to its kinematic scheme and given orientation ( $A_1, A_2, \dots, A_n$ ) its links ( $n$  – the number of degrees of freedom of the manipulator,  $A$  – angles of rotation). The solution of the direct kinematics problem determines the position of manipulator at given angles of its joints [1].

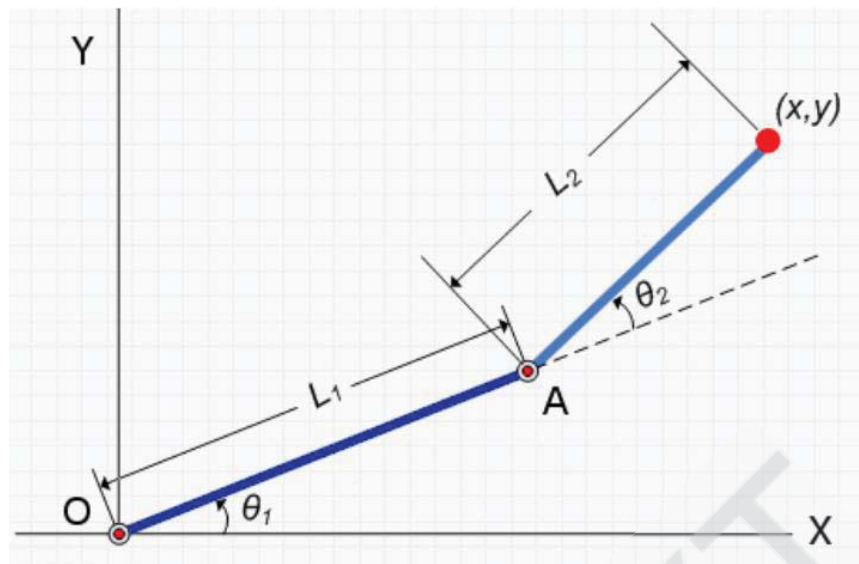


Fig. 1 - Kinematic scheme of the two-link manipulator

The inverse of kinematics, in contrast, allows us to determine angles  $(A_1, A_2, \dots, A_n)$  by a given position  $(X, Y, Z)$  manipulator and kinematics scheme. By solving the inverse kinematics problem, one finds out how to move the manipulator in order to get it in the right position.

It should be noted that in solving the direct kinematics problem the solution can be only one, because there is a single position of manipulator  $(X, Y, Z)$  with the angles  $(A_1, A_2, \dots, A_n)$ . However, solving the inverse problem of kinematics may be in several solutions: the achieving a given position  $(X, Y, Z)$  can occur with different combinations of angles  $(A_1, A_2, \dots, A_n)$  (fig. 2).

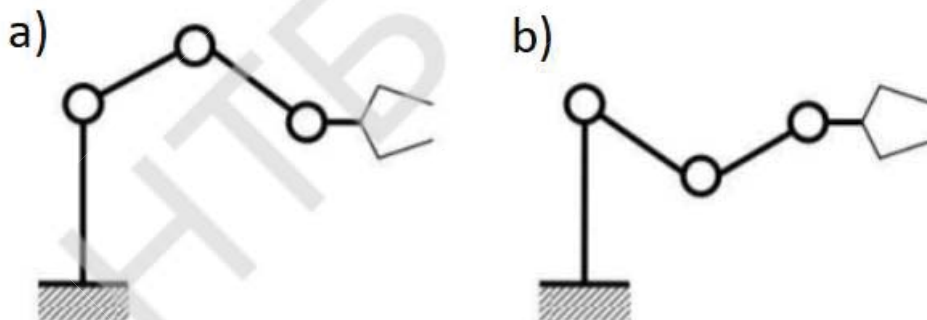


Fig. 2 - Kinematic scheme of the two-link manipulator  
a) links above; b) links below

For our research topic is more important the solving of inverse kinematics problem.

#### IV.II Solution of inverse kinematics problem

The task is to find the angles  $\theta_1$  and  $\theta_2$  that would allow the manipulator with the link  $L_1$  and link  $L_2$  to move the manipulator to a given point  $(x, y)$  (fig. 3).

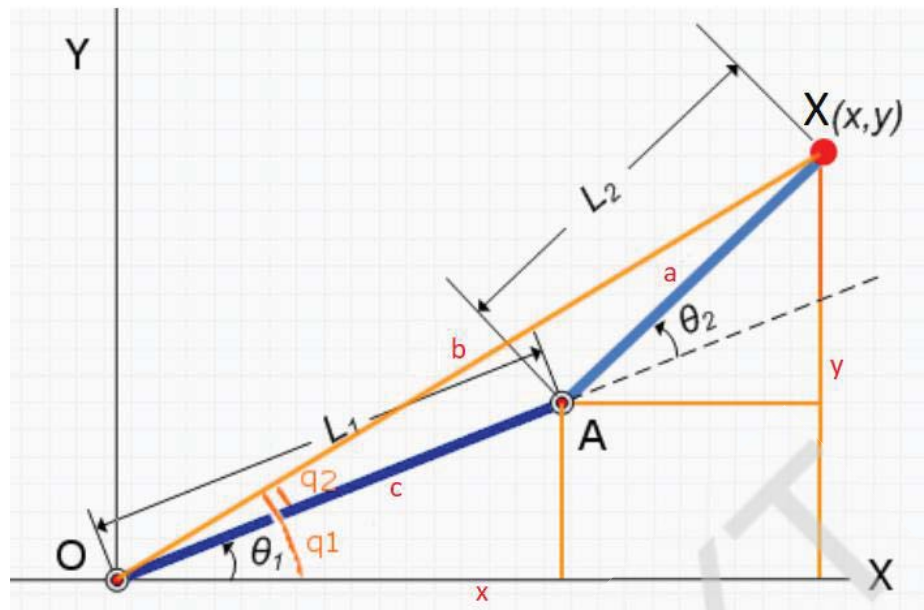


Fig. 3 - Kinematic scheme of the manipulator

Draw a straight line  $b$ , which connects the origin ( $p. O$ ) and the point at which the manipulator takes a given position ( $p. X$ ).

$q_1$  – the angle between the abscissa and  $b$ .

According to Pythagorean theorem:

$$b^2 = x^2 + y^2.$$

From here

$$\cos(q_1) = \frac{x}{b}, \quad x = b * \cos(q_1);$$

$$q_1 = \arccos\left(\frac{x}{b}\right);$$

$$\sin(q_1) = \frac{y}{b}, \quad y = b * \sin(q_1);$$

$$tg(q_1) = \frac{y}{x}, \quad q_1 = \arctg\left(\frac{y}{x}\right).$$

Let us denote:

$q_2$  – the angle between the  $b$  and  $L_1$ ;

$\theta_1$  – angle, which is necessary to return the working body of the manipulator to achieve a given position.

Then  $\theta_1 = q_1 - q_2$ .

Find  $q_2$  using the cosine theorem:

$$L_2^2 = b^2 + L_1^2 + 2 * b * L_1 * \cos(q_2);$$

$$2 * b * L_1 * \cos(q_2) = b^2 + L_1^2 + L_2^2;$$

$$\cos(q_2) = \frac{b^2 + L_1^2 + L_2^2}{2 * b * L_1};$$

$$q_2 = \arccos\left(\frac{b^2 + L_1^2 + L_2^2}{2 * b * L_1}\right).$$

Now find  $\theta_2$ . Consider the triangle OAX (fig. 3):

$$\theta_2 = \pi - \angle OAX;$$

Find  $\angle OAX$  using the cosine theorem:

$$b^2 = L_1^2 + L_2^2 - 2 * L_1 * L_2 * \cos\angle OAX;$$

$$2 * L_1 * L_2 * \cos\angle OAX = L_1^2 + L_2^2 - b^2;$$

$$\angle OAX = \arccos\left(\frac{L_1^2 + L_2^2 - b^2}{2 * L_1 * L_2}\right);$$

Then the required angles  $\theta_1$  i  $\theta_2$  can be defined as follows:

$$\theta_2 = \pi - \arccos\left(\frac{L_1^2 + L_2^2 - b^2}{2 * L_1 * L_2}\right);$$

$$\theta_1 = \arccos\left(\frac{x}{b}\right) - \arccos\left(\frac{b^2 + L_1^2 + L_2^2}{2 * b * L_1}\right).$$

It should be noted that the solution of the inverse kinematics problem requires minimizing the distance at which the manipulator's working body needs to change position.

#### **IV.III Degrees of freedom (DoF)**

The number of degrees of freedom determines the minimum number of independent variables required to fully describe the motion of a particular mechanical system [2].

A distinction is made between the translational and rotational degrees of freedom. The translational degree implies movement in a straight line, while the rotational degree of freedom implies the presence of some mechanical system of axes of rotation.

By the number of degrees of freedom mechanical systems are divided into holonomic and nonholonomic [3]. A holonomic mechanical system is a mechanical system which has 6 physical degrees of freedom, and nonholonomic - when a system has less than 6 physical degrees of freedom.

#### **IV.IV Coordinate system**

A coordinate system is required for mathematical describing the motion of a robot.

A distinction is made between the following coordinate systems [2]:

- W (World) – world's coordinate system. It is characterized by constancy and motionless.
- R (Robot) – robot's coordinate system. It is characterized by changes in space, but it remains motionless to the robot.

#### **IV.V Path-planning**

In the case where the robot knows the location of the target point and its relation to the world's coordinate system, it becomes possible to move the robot along some sequence of points that are determined in advance [2]. Various curvilinear trajectories are planned to provide the further optimization of the path with minimization the time spent on movement and energy consumption.

The movement of robot consists of straight segments separately from turns in place. As the robot tries to minimize the total distance of the path, it always rotates the way the direction vector of its motion points to the next point and goes straight to it. It continues until the robot reaches its target point.

The current position of the robot can be described by vector X:

$$X = (x, y, \theta).$$

where x, y – location of the point of the center of work according to the world's coordinate system;  $\theta$  is the angle of rotation between the coordinate systems W and R.

The location of the next waypoint to which the robot follows can be described this way:  $A = (W_x, W_y)$ . The fig. 4 shows robot's moving to the next target point.

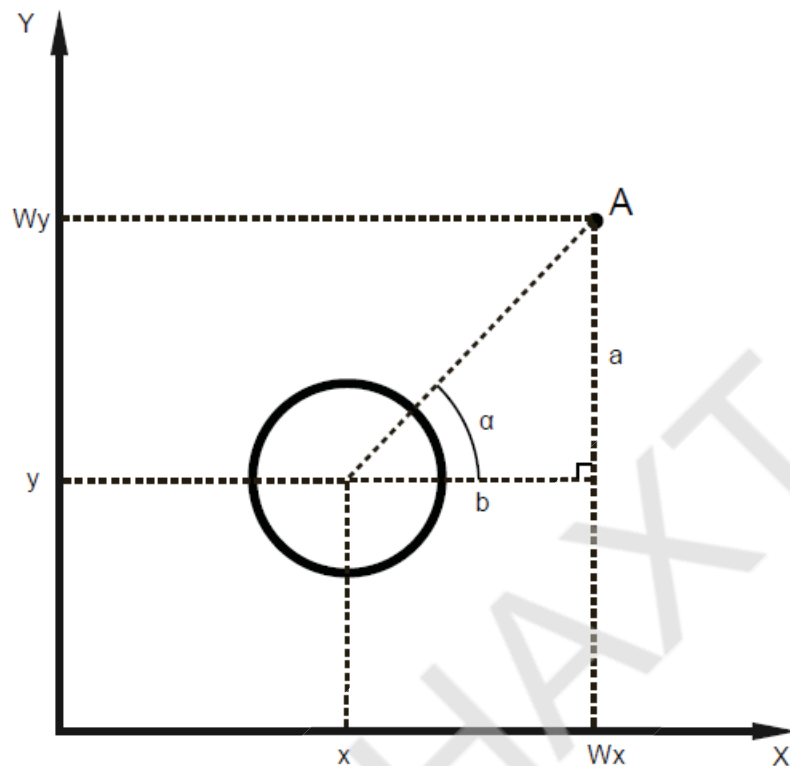


Fig. 4 – Path-planning

Firstly, robot returns to the next waypoint. To do this, we have to find the angle  $\alpha$ , at which the robot must return.

Find the offset relative to abscissa and ordinate that will occur because of robot's moving from the current point to the following:

$$W_x - x = b;$$

$$W_y - y = a.$$

$$\text{Then } \text{tg}\alpha = \frac{a}{b} = \frac{W_y - y}{W_x - x}, \alpha = \text{arctg} \frac{W_y - y}{W_x - x}.$$

Since the robot has already returned to some angle, the angle to which the robot must be returned can be noted as follows:

$$\beta = a - \theta.$$

Now we need to find the distance that the robot needs to overcome by moving at a given angle to the next point.

Let us denote:  $d$  – the distance at which the robot has to move in a straight line. It can be found by using Pythagoras' theorem:

$$d = \sqrt{a^2 + b^2} = \sqrt{(W_y - y)^2 + (W_x - x)^2}.$$

#### IV.VI Supervised learning

Machine learning is a unit of artificial intelligence that studies methods of constructing algorithms capable of learning [4]. Thus, the idea of machine learning is the fact that the machine has learned itself to solve some problems, but cannot solve it with the already known algorithm.

It should be noted that while the machine is capable of predicting, memorizing and selecting the best option, it still cannot create a new one [5].

Classical teaching is the one of machine learning's types which can be divided into supervised learning and unsupervised learning. In supervised learning machine is trained on examples set input already contains the necessary input and output values. The algorithm should establish how the input values are obtained by means of analysis, identification of various regularities. In this way machine learns from observations and is capable to make predictions. These predictions are adjusted by the operator. The process continues until the algorithm reaches the required accuracy [6].

Among the problems that are solved with the help of supervised learning there are problems of classification and regression. In solving the classification problem, the machine has to conclude to which category the new object belongs, and in regression - determine the location for the object on a numerical line relative to the previous analysis of the relationship between the variables.

### **IV.VII The use of supervised learning**

Classification is widely used for spam filters, language detection, handwriting and number recognition, suspicious transaction detection, definition object's type in a photo, spam/ham distribution. The most popular algorithms are Naive Bayes classifier (previously used for spam filters), Decision tree, Support-vector machine [5].

Thus, regression is used to predict the value of securities, beat and sell analysis, and when there is a time dependence. A distinction is made between linear and nonlinear regression, depending on what curve the regression draws: if a straight line is a linear regression, if a curve is a nonlinear regression.

Now a variety of companies are developing methods by which machines can learn new things. It makes the use of machine learning an important step in development of robotics. For example, in a new Google lab, specialists were developing a manipulator that sorts the trash in the recycle bin [7]. Thus, as the manipulator is equipped with a camera it analyzes objects using classification and learns to sort objects by different categories. It should be noted that this technology has proven itself well in a laboratory, but sometimes there are difficulties in a distribution center, because the robot can face unknown objects or tasks that require movement, which the robot has not done before. That's why it makes mistakes.

Specialists have also been teaching mobile robot to orientate in unknown areas. Such robots can be useful in warehouse work [7]. Here, regression can be used to construct the path which allows the robot to reach the destination point.

That is, depending on the sphere of using there can be created robots with their further learning. These robots will receive the information from various sensors (photo sensor, camera, motion sensor) and facilitate human labor.

### **V. Conclusion**

In this science paper there were introduced the kinematics of the robot, the solution of the inverse kinematics problem on the example of a manipulator, the concept of the degree of freedom and the coordinate system. It has been found that mechanical systems can be divided on holonomic and nonholonomic according to the number of degrees of freedom.

Also there were considered the process of path-planning, constructing a curvilinear trajectory, describing the current location of the robot and finding the necessary angle and distance for robot's moving to the next waypoint.

In the course of the work, it was found out that machine learning is a topical subject in the modern world and is a unit of artificial intelligence. Classification and regression were reviewed as the main tasks of supervised learning. There were discussed the possibilities of using in various spheres of human life and given examples of applications in robotics.

The application of machine learning is a topical issue for the modern world and has a great potential for further development. The use of machine learning in robotics can simplify human performance, do it faster and more efficiently. Some companies have already involved in machine learning, such as Google Labs developing a manipulator that can be used for sorting trash based on classification. The main problem now is to transfer this technology to the real world because the robot may encounter objects and tasks that are unknown to it.

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## **THE ALGORITHM OF INFORMATION SECURITY RISK ASSESSMENT BASED ON FUZZY-MULTIPLE APPROACH**

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***Abstract.** The subject of the study is the process of assessing the level of information security risk that is being implemented with the help of the fuzzy logic apparatus. The purpose of this work is to develop a methodology for assessing the degree of information security risk, which would avoid the uncertainty factor, that occurs when some parts of*