POSITIONAL MODELING OF THE 2T6R ROBOT MECHANISM

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ABSTRACT

The positional modeling of the 2T6R robot mechanism is done for inverse kinematics, i.e. when the imposed positions of the end effector T, imposed, belonging to the final element 3, are known and the necessary positions and speeds of the two input motors, the two leading elements, are determined, 1 and 6. It is proposed to solve a simple algorithm in the program MathCad 2000, which uses for initiation the logical function If Log. The kinematic output parameters, i.e. the parameters of the foot and practically of the final effector, i.e. those of the point marked with T, will be determined for initiating the working algorithm using the logical functions, "If log (ical)", with the observation that here plays the role of parameters input; is positioned as already specified in reverse kinematics when the output is considered as input and input as output. The logical functions used, as well as the entire calculation program used, were written in Math Cad 2000.

Keywords: If Log; Math Cad; Robot; 2T6R robot; Kinematics; Inverse kinematics
1. INTRODUCTION

The industrial robot is an integrated mechanical electronic informational system, used in the production process in order to achieve manipulation functions analogous to those performed by human hands, giving the manipulated object any freely programmed movement, within a technological process that takes place in a specific environment.

Intelligent robots represent the highest stage of development, at which the sensors are much more numerous and more complex, there are specific blocks and subsystems for moving and orienting their sensors, for measuring their movement, for processing information.

1) Trajectory generating mechanism (MGT): the mechanism formed by those kinematic couplings that make possible the displacement of the characteristic point M on the imposed trajectory. To generate the T trajectory, 3 degrees of freedom are also necessary: rotation around the Oz axis; vertical displacement along the Oz axis, and a radial displacement along the x-axis.

2) The orientation mechanism (MO) is the mechanism formed by the kinematic couplings that ensure the spatial orientation of the object, ie the mechanism that rotates after x ', y', and z ' (palm-forearm of the human hand).

3) The gripping mechanism (MP) ensures the gripping and fixing of the manipulated object. If instead of handling we need welding, painting, cutting, processing, measuring ..., then the end effector will no longer be a gripper (gripping hand) but another corresponding final effector element.

Classification in terms of trajectory generation:

Robots with continuous positioning (in which the trajectory is generated continuously), which involves special blocks for correlating movements on 2 or 3 degrees of freedom, are called motion interpolators. The drive system and the control system must be suitable for this mode of operation. There must always be a well-defined bi-univocal correspondence between the command-movement.

The control system must be able to manage the movements on each degree of freedom and to correlate the movements with each other, in the sense of generating the mathematically described trajectory. Controllers, sensors, motion limiters are needed, in addition to the actuation system with actuators (electric or hydraulic motors, rarely pneumatic), for actuation, command, and permanent control of the realized movement.
The controller is in fact a microchip, a microprocessor, which controls the whole process of the robot, from head to tail, through system drivers some specialized programs that control all the movements of the robot, these drivers being in constant contact with the machine, system, and computer, direct and reverse connections. The control drivers perform practically all the necessary commands, in the sense that they will move from the microchip (central unit and controller) to the robot, actuators (motors) effectively commanding the necessary imposed or self-detected movements (to the latest generation intelligent robots).

The drivers also check the execution of the movement by the entire robot mechanism and if the elements of the robot mechanism are in the indicated parameters (prescribed by the controller and microprocessor). In particular, the permanent positions of the end-effector end element, with the end-effector point T, its trajectory, and the sequential positions occupied in time are checked, so that they correspond to the commands given by the microprocessor, and the controller verifies their accuracy within certain prescribed limits. Whether the final element is within the prescribed limits or not is communicated by the sensors that permanently check the system parameters.

There are sensors for motion, speed, acceleration, shock, temperature, pressure ... The sensors give the reverse signal showing what happens to the whole system and especially to the final element end effect at any given time, and if the parameters of a point, but especially those of the final element, of the T point tracer, or effector, do not correspond at a given moment, the necessary correction is made immediately, the movement to the next step being corrected accordingly on each axis, more or less as the case may be.

The role of the limiters is not to let certain moving elements exceed certain limits. For example, they will stop the rotational movement reaching a certain angle and will control the reverse movement, ie the reverse rotation to the other end where the process will be reversed again. Both motion sensors and limiters are built according to the principles of transmitters, being generally very small.

There are also robots with sequential positioning.

Mechanic geometric parameters: Guide device: the set of all kinematic torques that compete to achieve the trajectories and spatial orientation of the manipulated objects within the imposed limits (MGT + MO). Final effector: clamping mechanism (in case of handling robots) or device (in case of specific operations). Load capacity: the maximum size of the mass that can be
handled, in conditions of total safety, for the most unfavorable position of the robot and for the highest value of the acceleration that can develop it, in ascending vertical movement.

Unfavorable position: that position of the gripping mechanism, in which the manipulated object is maintained and moved only under the effect of the frictional forces, generated by the tightening action between the object and the ‘fingers’ of the mechanism. Normalized load-bearing capacities: 0.250; 1; 2.5; 6.4; 10; 25; 64; 100 ... etc.

Classification of robots according to the value of load-bearing capacity: Microrobots (tens of grams); Minirobots (hundreds of grams); Medium robots (of the order of kilograms); and Heavy robots (of the order of hundreds of kg); (Antonescu & Petrescu, 1985; 1989; Antonescu et al., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; Atefi et al., 2008; Avaei et al., 2008; Aversa et al., 2017a; 2017b; 2017c; 2017d; 2017e; 2016a; 2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; 2016j; 2016k; 2016l; 2016m; 2016n; 2016o; Azaga & Othman, 2008; Cao et al., 2013; Dong et al., 2013; El-Tous, 2008; Comanescu, 2010; Franklin, 1930; He et al., 2013; Jolgaf et al., 2008; Kannappan et al., 2008; Lee, 2013; Lin et al., 2013; Liu et al., 2013; Meena & Rittidech, 2008; Meena et al., 2008; Mirsayar et al., 2017; Ng et al., 2008; Padula, Perdereau & Pannirselvam, 2008; 2013; Perumal & Jawahar, 2013; Petrescu, 2011; 2015a; 2015b; Petrescu & Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e; 2011a; 2011b; 2012a; 2012b; 2013a; 2013b; 2016a; 2016b; 2016c; Petrescu et al., 2009; 2016; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae; 2018a; 2018b; 2018c; 2018d; 2018e; 2018f; 2018g; 2018h; 2018i; 2018j; 2018k; 2018l; 2018m; 2018n; Pourmahmoud, 2008; Rajasekaran et al., 2008; Shojaeefard et al., 2008; Taher et al., 2008; Tavallaee & Tousi, 2008; Theansuwan & Triratanasirichai, 2008; Zahedi et al., 2008; Zulkifli et al., 2008).

A special character in the study of robots is the study of inverse kinematics, with the help of which the map of the motor kinematic parameters necessary to obtain the trajectories imposed on the effector can be made. For this reason, in the proposed mechanism, we will present reverse kinematic modeling in this paper. The kinematic output parameters, i.e. the parameters of the foot and practically of the end effector, i.e. those of the point marked with T, will be determined for initiating the working algorithm with the help of logical functions, " If Log(ical)", with the observation that here they play the role of input parameters; it is positioned as already specified in
the inverse kinematics when the output is considered as input and the input as output. The logical functions used, as well as the entire calculation program used, were written in MathCad 2000.

2. METHODS AND MATERIALS

The positional modeling of the 2T6R robot mechanism is done for inverse kinematics, i.e., when the imposed positions of the end effector T, imposed, belonging to the final element 3, are known and the necessary positions and speeds of the two input motors, the two leading elements, are determined, 1 and 6. It is proposed to solve a simple algorithm in the program MathCad 2000, which uses for initiation the logical function If Log.

The kinematic output parameters, i.e., the parameters of the foot and practically of the final effector, i.e., those of the point marked with T, will be determined for initiating the working algorithm using the logical functions, "If log (ical)", with the observation that here plays the role of parameters input; is positioned as already specified in reverse kinematics when the output is considered as input and input as output. The logical functions used, as well as the entire calculation program used, were written in Math Cad 2000.

If it is desired that a point T of the execution element realizes a sequence of sequences on a trajectory required by a certain process it is necessary that through the inverse model to establish the kinematic parameters of the active torques. The dynamic parameters and consequently their actuation according to the process can be determined using the directly associated model. In the following, these characteristics for a 2T6R type manipulator robot are analyzed in detail.

The bimobile mechanism of Figure 1 can be used in various handling applications or in technological processes. There are six movable kinematic elements and eight kinematic couplings, of which two active kinematic couplings of translation A and D. The mechanism can achieve with the T end of the effector 3 any curve in a certain plane domain. It is obtained from the bimobile and bicontour kinematic chain of Figure 2a from which derives the direct structural model (Figure 2b) for which the base, the effector, as well as the active kinematic torques are nominated.

The kinematic scheme of the 2T6R plan robot presented with two cylindrical drive motors is arranged in figure 1.
Figure 1: The kinematic scheme of the 2T6R plan robot presented with two cylindrical drive motors

Figure 2: Structural scheme of the 2T6R mechanism

The connection of the modular groups (Figure 3) corresponding to the direct structural model (Figure 2b) comprises two initial active modular groups respectively GMAI (A, 1) and GMAI (D, 6), and two passive modular groups of dyad type, i.e. GMP1 (2.5) and GMP1 (3.4).

Figure 3: The connection of the modular groups corresponding to the direct structural model (Figure 2b), comprises two initial active modular groups respectively GMAI (A, 1) and GMAI (D, 6), and two passive modular groups of dyad type, i.e. GMP1 (2.5) and GMP1 (3.4).
The structural model directly is used to establish the algorithm for calculating the components of the reaction torque in the kinematic torques based on the kinetic-static calculation modules.

The inverse structural model (Figure 4a) of the mechanism allows the determination of the parameters of the active torques A and D depending on the characteristics of the T point required by the technological process in which the system is used, representing the theme presented in this paper.

In the inverse structural model the passive modular group GMP8 from Figure 4b. In the connection of the groups (Figure 5) this structure is noticeable.

![Figure 4](image)

**Figure 4:** The inverse structural model (Figure 4a) of the mechanism allows the determination of the parameters of the active torques A and D depending on the characteristics of the T point. In the inverse structural model (Figure 4b) the passive modular group GMP8.

![Figure 5](image)

**Figure 5:** The connection of the groups GMP8(1, 2, 3, 4, 5, 6)

### 3. RESULTS AND DISCUSSION

The constant geometric parameters of the mechanism of Figs. 1 are listed in Table 1.

| Table 1: Constant geometric parameters |
|-----------------------------------------|
| TB     | 1.     |
| TC     | 0.8    |
| AE     | 0.3    |
| EB     | 0.8    |
| AB     | 1.1    |
| DC     | 0.8    |
| DE     | 0.3    |
| XA     | 0.     |
| YD     | 0.     |

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The input parameters of the point T corresponding to a trajectory, for example, rectilinear and alternative for a certain interval are shown in Table 2 and plotted in FIGURE 6.

| Initial parameters of the T point trajectory |
|---------------------------------------------|
| Initial parameters of the T point           |
| T0(-0.2, -0.8)                              |

The description of the input parameters for the inverse model of the mechanism is presented in table 3. The trajectory of the T point represented in figure 6 is thus described.

Table 3: Input parameters

| Coordinates of the current point T          |
|---------------------------------------------|
| XT_k:=if[k≤10,XT0+k·0.05,XT0+10·0.05-(k-10)·0.05] |
| YT_k:=YT0                                   |

Figure 6: The trajectory of the point T

Figure 7 shows the dependent positional parameters for the inverse model of the mechanism. The algorithm for their determination is given in Table 4 and uses the connection of the modular groups of the inverse model (Figure 5).

Figure 7: The dependent positional parameters for the inverse model of the mechanism
The GMP 8 passive modular group (Figure 4b) has the following dependent parameters: \( Y_A(X_T, Y_T), \ X_D(X_T, Y_T), \ \Phi_2(X_T, Y_T), \ \Phi_3(X_T, Y_T), \ \Phi_4(X_T, Y_T), \ \Phi_5(X_T, Y_T) \).

### Table 4: passive modular group

| The pattern | Position-dependent parameters |
|-------------|-----------------------------|
| GMP8(1,2,3,4,5,6) | \(AB \cos(\phi_2) = XT_k + TB \cos(\phi_3)\)  
\(YA + AB \sin(\phi_2) = YT_k + TB \sin(\phi_3)\)  
\(XD + DC \cos(\phi_4) = XT_k + TC \cos(\phi_3)\)  
\(YD + DC \sin(\phi_4) = YT_k + TC \sin(\phi_3)\)  
\(AE \cos(\phi_2) = XD + DE \cos(\phi_5)\)  
\(YA + AE \sin(\phi_2) = DE \sin(\phi_5)\) |
| BPT(C) | \(XC_k = XT_k + TC \cos(\phi_3_k)\)  
\(YC_k = YT_k + TC \sin(\phi_3_k)\) |
| BPT(B) | \(XB_k = XT_k + TB \cos(\phi_3_k)\)  
\(YB_k = YT_k + TB \sin(\phi_3_k)\) |
| BPT(E) | \(XE_k = XA_k + AE \cos(\phi_2_k)\)  
\(YE_k = YA_k + AE \sin(\phi_2_k)\) |

Variation of the parameters of the active kinematic translation couples \( Y_A(X_T, Y_T), \ X_D(X_T, Y_T) \) can be seen in the Figure 8a and Figure 8b.

![Variation of the parameters of the active kinematic](https://example.com/figure8.png)

**Figure 8:** Variation of the parameters of the active kinematic

Similarly, the variation of the angular parameters (expressed in degrees) noted \( \Phi_{20}(X_T, Y_T), \ \Phi_{30}(X_T, Y_T), \ \Phi_{40}(X_T, Y_T), \ \Phi_{50}(X_T, Y_T) \) will be represented graphically in figure 9.
To perform the kinetostatic analysis it is necessary to determine the parameters of the kinematic couples marked with C, B, E, the trajectories being shown respectively in Figure 10a, FIGURE 10b and FIGURE 10c.

4. CONCLUSIONS

A special character in the study of robots is the study of inverse kinematics, with the help of which the map of the motor kinematic parameters necessary to obtain the trajectories imposed on the effector can be made. For this reason, in the proposed mechanism, we will present reverse kinematic modeling in this paper.

If it is desired that a point T of the execution element realizes a sequence of sequences on a trajectory required by a certain process it is necessary that through the inverse model to establish the kinematic parameters of the active torques. The dynamic parameters and consequently their actuation according to the process can be determined using the directly associated model. In the following, these characteristics for a 2T6R type manipulator robot are analyzed in detail.
The bimobile mechanism of Figure 1 can be used in various handling applications or in technological processes. There are six movable kinematic elements and eight kinematic couplings, of which two active kinematic couplings of translation A and D. The mechanism can achieve with the T end of the effector 3 any curve in a certain plane domain. It is obtained from the bimobile and bicontour kinematic chain of Figure 2a from which derives the direct structural model (Figure 2b) for which the base, the effector, as well as the active kinematic torques are nominated.

Inverse kinematic modeling is generally the most sought after, as the most important, but in most situations, it is also the most difficult to determine. In the presented paper, the MathCad2000 software was used in order to facilitate the calculations, because the software automatically solves the linear and nonlinear systems through its internal procedures that must be called within the program.

As an important function, the "IfLog" logic function was used twice in the program to initiate the calculations, by determining the input variables in the inverse kinematics.

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7. ETHICS

Authors should address any ethical issues that may arise after the publication of this manuscript.

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