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Structural Synthesis, Work Spaces and Direct Kinematic of the one Serial Kinematic Chain with 8 Axes for Industrial Robots

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Abstract

In this paper, for a useful working basis, including for the promotion of new redundant structures, beyond those already implemented, there is a systematization of kinematic chain structures with 8 axes. Representation of corresponding workspaces can help the designer in choosing the structure with maximum functionality for a given application. Exemplifying of the use of these redundant structures, namely a structure with 8 axes, is possible presenting the eight-axes robot CLOOS, of type: T L R | (R | R | R | R ). For this version the workspace is represented, first sequentially, successively for each coupling, starting with the translation coupling from the kinematic chain base and then the workspace is represented totally by overlapping workspaces obtained for each coupling. Below we present the direct kinematics analysis for this kinematic chain using the homogeneous operators’ method. This method is based on the use of homogeneous translation or rotation operators and covering the kinematic chain from the base to the characteristic point at its end by a mobile reference system. Transition from a coupling to another is associated with a matrix homogeneous operator of translation, rotation, translation-translation, rotation-rotation or combined (translation-translation or translation-rotation). Based on linear and angular dimensions expressed in matrix by corresponding homogeneous operators we obtain the matrix of the robot characteristic point coordinates in the fixed reference system attached to the robot base. Thus, direct kinematics is solved qualitatively. For a set of numerical values, we obtain a quantitative solution.

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1. Introduction

Current it was agreed that the kinematic chain of an industrial robot must have 6 axes (3 axes corresponding to the positioning kinematic chain and 3 axes corresponding to the orientation kinematic chain, forming together the kinematic guiding chain), any additional number of axes (monomorphic kinematic couplings), leading to a certain redundancy. Current it was considered that redundant kinematic chains are not desirable because they increase the complexity unnecessarily, there is more time needed to calculate trajectories and costs are higher. In recent years, 2-4 years ago, however there are concerns for the promotion and realization of industrial robots with redundant kinematic chains, especially those with 7 axes, but also with 8 axes [1,2,3,4,5,6,7,8,9,10,11,12]. They have proven that they have larger workspaces and increased possibilities for maneuvering in these spaces and the disadvantages mentioned have significantly reduced their importance by increasing the speed of computation of trajectories due to the explosive growth of computing power of the processors used, reducing design, and manufacturing costs, and the more complicated structure has become virtually a very important functional advantage. In this paper, we make a systematic summary of kinematic chains structures with 8 axes and for a kinematic chain with 8 axes, applied at CLOOS robot, we exemplify the workspace and give an example of qualitative computing of direct kinematics applying the method of homogeneous operators.

2. Systematization of kinematic chains with 8 axes for robots

Current, the structures of kinematic chains with 8 axes can be obtained from 6-axis ones, by the addition of two axes (two kinematic monomorphic couplings) of rotation or translation, or combinations RT, respectively, TR. These axes are added at one end of the kinematic chain of six axes (guiding kinematic chain) or between the positioning kinematic chain and the orientation kinematic chain. Other possibility is to add one at one end and the other at the other end of the positioning kinematic chain or the orientation kinematic chain, or by the addition of an R or T axis to the 7-axis structure. This additional axis is added similarly to the case of obtaining structures with seven axes of the 6-axis ones, having parallel or perpendicular position to the opposite axis. Guiding 7-axis kinematic structures are obtained from 6-axis ones. So, they are seven monomorphic kinematic R or T couplings, relatively perpendicular or parallel. This is possible by adding a monomorphic kinematic coupling (an additional axis) of rotation (R) or translation (T). This coupling may be added at the beginning, at the end of the guiding kinematic chain or between the two component kinematic chains, between the positioning and the orientation kinematic chains. To obtain all possible combinations without losing the functionality of the positioning and orientation kinematic chains, we consider the positioning kinematic chain a distinct kinematic module called positioning module (PM) and the orientation kinematic chain, a kinematic module called orientation module (OM). The relative position of the seventh coupling (axis) to the first or the last coupling of one of the two modules can be perpendicular (⊥) or parallel (∥). 12 possible combinations are obtained: R⊥PM(OM), R∥PM(OM), T⊥PM(OM), T∥PM(OM), PMR(OM), PMR(TOM), PMR(TOM), (PM)R(OM), (PM)R(TOM), (PM)R(TOM), R, (PM)(OM)]R, (PM)(OM)]T, (PM)(OM)]P. As a result, we obtain a number of different structures that correspond to non-degenerate working spaces corresponding to positioning kinematic chains of this type, which, according to [13] are in number of 20. The result is 12 * 20 = 240 kinematic chain structures with 7 axes. By adding a rotation (R) and a translation (T) coupling, perpendicular (⊥) or parallel (∥) to the four first structures (RT)[(∥)](PM)(OM)] of the kinematic chains with seven axes we obtain 16 structures of kinematic chains with eight axes: R⊥RT(OM)(OM), R∥RT(OM)(OM). Similarly, structural versions with 8 axes are obtained, on the basis of seven-axis structures such as (PM)[(∥)](R)(OM)] and (PM)(OM)[(∥)](R)/(T). We obtain finally 96 versions, 16 for each combination such as (RT)[(∥)](R)(OM)] and (PM)(OM)[(∥)](R)/(T). In Fig.1 there are two kinematic structures with 8 axes, with representation in [14] of the structure of the redundant positioning module (PM: 3 plus 2 axes: R∥(R∥R∥R) ⊥ T and T∥(R∥R∥R) ⊥ T) and condensed of the orientation module (OM; 3 rotation axes: R∥R∥R). Appropriate structural schemes may be represented for all the 96 different possible combinations.
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