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Evaluation Parameters for the Functional Performances of the Industrial Robots

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Abstract

This paper presents an original procedure for the efficient evaluation of the functional performances of the corporate industrial robots, produced nowadays in a great variety, so that for a given application with an expert system to make possible the selection of the most suitable robot.

Key words: *industrial robot, parameters, expert system, time delay, typical time.*

Introduction

The technical characteristics of the industrial robots include, according to the application which they have been conceived for: dimensions, values of the possible movements, the precision, the repeatability, number of degrees of freedom, the type of operation, the mass of the robot, the volume of the working zone, command – control capacity of the system, speed of movement/ displacement, possible processing and execution time, the transportable charge, the possibility of controlling more working arms.

For conceiving a given application (for example a given assembly process), by means of an autonomous robot integrated into the working machine, it is necessary to choose a robot which will fulfil some characteristics (resulting from the application) and will lead to the expert system for generating the technological states.

Parameters Groups

The performances of the industrial robots may be defined, according to the present international standards, by the next four groups of parameters:

- global parameters;
- translation and rotation movement parameters (of the type REACH and MOVE);
- clips handling parameters (of the type ORIENT, GRASP, RELEASE);
- time parameters.

The last three groups of parameters of the robot are used by the expert system to generate the technological route, goal for which there are conceived graphical interfaces which are necessary to introduce the data describing the route in the database of the system.

All the constructive types of robots are characterized by the parameter *characteristic time* (TC) defined for every possible movement of the robot. The characteristic time expresses the duration, in seconds, necessary for the robot to make a movement of *l* cm (for the linear movement of translation) or *l* deg (for the rotational movement of the arm of the robot).

In this way, there are evaluated parameters as: TC expands, TC retrieve, TC goes down, TC goes up, TC grasps (all expressed in s/cm), TC rotates (expressed in s/deg). For example, an industrial robot of ASEA type can have the following characteristics times, characteristic for the movement of type GRASP and RELEASE: TC grasp = TC release = 0.01s.

Global Parameters

These parameters form the first group of parameters and they are expressed using the symbols k_1, k_2, k_3 which are defined as follows:

- the global parameter k_1:

k_1 = (the volume of the working zone, [m^3]) / (the service weight of the industrial robot, RI, [N])

The parameter k_1 characterizes the industrial robot (RI) from the point of view of its reaction efficiency in the industrial environment with certain suppleness. Here, by the service weight, it is understood the weight of the RI in functioning conditions;

- the global parameter k_2:

k_2= (the weight of the manipulated object, [N]) / (the service weight of the RI, [N])

This parameter characterizes the industrial robot (RI) from the point of view of the specific gravity capacity of manipulation;

- the global parameter k_3:

$$k_3 = \frac{(\text{the volume of the working zone, } [\text{m}^3]) \times (\text{the weight of the manipulated object, } [\text{N}])}{(\text{the service weight of the RI, } [\text{N}]) \times (\text{manipulation precision, } [\mu\text{m}])}$$

k_3 characterizes the technical characteristics of the industrial robots RI, which are considered "better" when k_3 is bigger.

Analyzing the performances defined by means of the global parameters, k_1, k_2, k_3, it is observed that to obtain the appropriate models for the given expert system, the parameters k_i, i = 1, 2, 3, must take their maximum possible values.

The Movement Parameters

According to the latest international standards, for notations and definitions, the TRANSLATION movement of the "working" arm is called MOVE and it expresses the displacement of the arm for service transport. This is noted *M* and it represents the necessary distance of displacement, evaluated in cm.

The movement of the arm without load is called REACH and it expresses the displacements of the arm without any load. This parameter is noted R_i, $i = 1, 2, \ldots, n$. Considering, as an example, a virtual industrial robot that has the scope of ranging some pieces (for depositing - delivery), which has an arm that can perform five different displacement operations, the movement parameters, *M* and *R*, are expressed as follows:

- M_1 & R_1 (extension movement of the arm of the type "lay the arm") evaluated using: *distance*, expressed in [cm], *speed*, in [cm/s], or using the characteristic time TC, given in [s];
- M_2 & R_2 (the movement of the arm of the type "move the arm"), indicated by: the displacement, in [cm], speed, [m/s], or TC, [s];
- M_3 & R_3 (movement on the vertical direction of the arm), which is expressed using the displacement [cm] and speed [m/s] or TC [s];

- o M_4 & R_4 (the rotation of the arm around its vertical axis), expressed using: the angular displacement [deg] and speed [deg/s].
- o O_3 (CLIP rotation around the vertical axis).
- o G_R (grasp the PIECE between the "JAWS" of the clip).
- o *RE* (releases the PIECE) etc.

For the evaluation of the functional performances of the robots it is used a series of global parameters as, for example:

- o C_1 – the cost of the robot, expressed in $;
- o C_2 – the mass of the robot [kg];
- o C_3 – the reliability of the robot, expressed using fuzzy multitudes (by means of attributes, compartation terms, adjectives, etc);
- o C_4 – the easiness of handling of the robot, expressed using fuzzy multitudes, etc.

The Temporary Parameters of the Robot

The present standards of the industrial robots define two temporary parameters that is:

- o PTD ("Process Time Delay") which expresses the temporary duration of the execution of the transport or orientation commands imposed by the technological operations which must be executed for finalizing the tasks of the realized application (depositing – delivery, assembly etc.).
- o TD ("Time Delay") which expresses the waiting time imposed to the robot for executing the technological operations of sticking and fixing.

To these temporary parameters there must be added – as necessary – other parameters, such as, for example, TC ("typical time") which is a specific constructive parameter of the robot which expresses the duration (given in seconds) of the processing of an angular movement/ displacement (a rotation) of one degree or of a linear movement of one centimetre.

According to this algorithm (imposed by the application for which the robot is used), which is executed by the robot, "step by step", commanded by the expert system, during a technological cycle, it can be calculated the duration TN of a cycle from the technological course, on condition that the parameters *S* (distances vector) are known and TC (the execution durations vector) for all the movements of orientation (OR and OM) and of translation R. The method is detailed by the author in his doctor degree thesis (Bogdan Mirodotescu, "Expert system for leading an autonomic robot", U.P.G. Ploiesti, 2007).

The definition and evaluation as precise as possible of these parameters allows the choice of the "most appropriate" (optimal) type of the robot that will be used for performing a given application, by using the expert system.

If *D* is the performances vector referring to execution duration (expressed in seconds) of a technological cycle, with scale value equal to the product of the vectors *S* (the characteristic distances of the technological process) and T^T (the transposition of the durations vector):

$$D = S \text{ x } T^{T} \tag{1}$$

The indicator *D* is calculated with (1) for more variants of industrial robots apparently adequate to the given application.

Being known, for every type of robot that could be chosen, the vector of the global parameters *C* (with C_1 – the cost in [$], C_2 – the mass of the robot in [kg], C_3 – the reliability of the robot), then on *C* and *D* can be formulated a problem of multicriterial decision regarding the most appropriate choice of the robot, from the point of view of the criteria C_1, C_2,…, C_n of *C*.

Conclusions

The technological route of the robotized application (of assembly, of processing, of depositing etc.) is composed by a sequence of technological operations done by autonomous robots equipped with adequate tools and led by expert systems. The industrial robotized processes are included in the category of the processes with discreet events that in the most of the cases are cyclic operations, preceded by the transport and positioning of the components. The synthesis of the technological route (composed by the succession of the technological operations imposed by the application) is performed by the expert system that is based on the correct choice of the parameters of evaluation of the functional robots.

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Parametri de evaluare a performanţelor funcţionale ale roboţilor industriali

Rezumat

Articolul prezintă o procedură originală pentru evaluarea eficientă a performanţelor funcţionale ale roboţilor industriali de firmă, produşi astăzi într-o mare diversitate, astfel încât pentru o aplicaţie dată cu sistem expert să se poată alege cel mai potrivit robot.