THE IMPLEMENTATION OF RTTRR SMALL-SIZED ROBOT IN A MICROPROCESSOR PACKING PROCESS

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ABSTRACT: The paper presents the implementation of the RTTRR small-sized robot in a process of microprocessor packing, as a final stage in a modern manufacturing line. After a brief presentation of the RTTRR small-sized robot, the work cycle and the work phases are described. The work cycle is split into ten phases, each of them being described in terms of generalized coordinate's variation with respect to time. By dividing each work phase into minimum three path segments, the method of path planning (4-3-4) can be applied, with the aim of determining the interpolation polynomials of the generalized coordinates, velocities and accelerations with respect to time.

KEY WORDS: robot path planning, manufacturing line.

1 INTRODUCTION

The parts robotic manipulation is an operation included in any technological process from a modern manufacturing line. The parts being manipulated could be: raw material, intermediary products, finite products, tools, packaging etc.

The paper presents the implementation of RTTRR small-sized industrial robot (figure 1), described in (Deteșan, 2007), into a process of microprocessor packing. The geometric and kinematic model of the robot was published in (Deteșan, 2015), and the dynamic model was presented in (Deteșan & Vahnovanu, 2016) and (Deteșan, 2016). These models are useful in the numeric simulation of the robot behavior under given kinematic and dynamic conditions.

2 WORK CYCLE DESCRIPTION

The figure 2 presents the implementation of RTTRR small-sized industrial robot in a microprocessor packing technological process. The robot (1) will be programmed to start from its zero configuration, to move in the proximity of the conveyor (2), to grip the microprocessor (3) in its gripper, to carry it over the packaging tray (4) and to release it in one of the five compartments of the tray (4). The packaging tray is presented in figure 3, together with its constructive dimensions.

The robot work cycle is divided in ten phases, each of them being split in path segments, according to figures 4 and 5. A useful way to plan the path of a robot is to determine the polynomial interpolation functions for the generalized coordinates, velocities and accelerations, using, for example, one of the path planning methods described in (Negrean, 2008): [5-(4-3-4)-5] method, (4-3-4) method, (3n) method without restrictions or (3n) method with restrictions.

A convenient method is (4-3-4), which was also presented and applied in (Detesan, 2013). By imposing initial conditions at the beginning of each phase, final conditions at the phases ends and continuity conditions in coordinates, velocities and accelerations when passing from one segment to another, the interpolation polynomials for the generalized coordinates will be obtained, of the 4th degree at end segments and of the 3rd degree for the intermediary segments, corresponding to each phase.

The polynomials describing the variation of the velocities and accelerations from the RTTRR robot's joints can be obtained by deriving with respect to time the variation functions of the generalized coordinates.

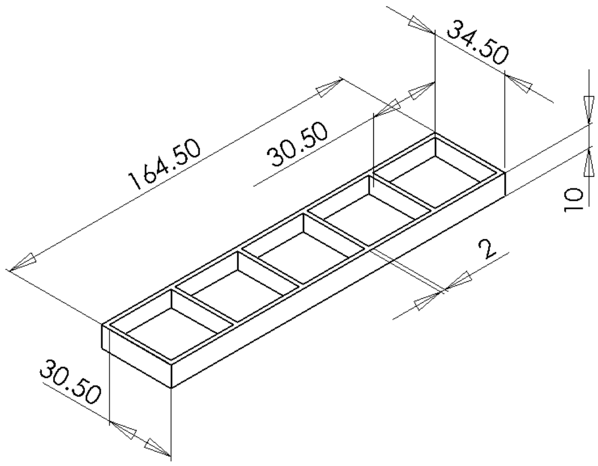

Figure 3. Partitioned tray for microprocessors

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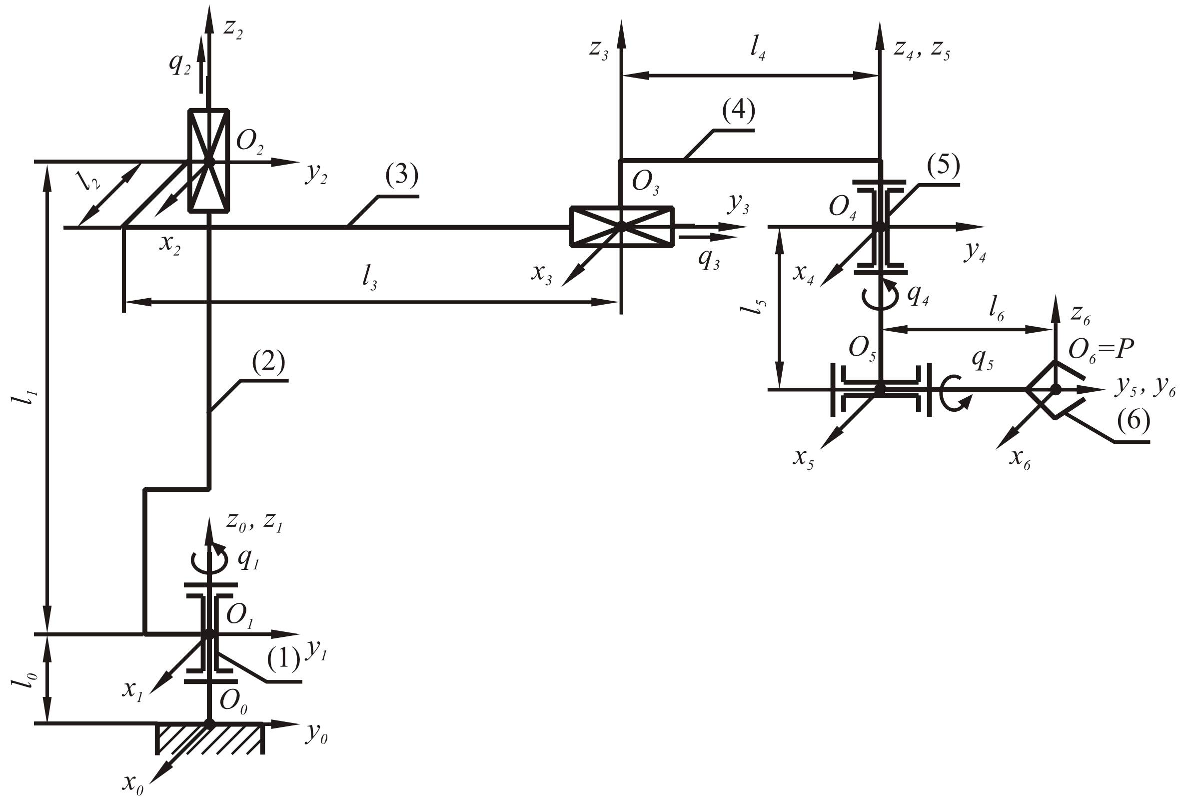

Figure 1. The kinematic sketch of RTTRR small-sized industrial robot

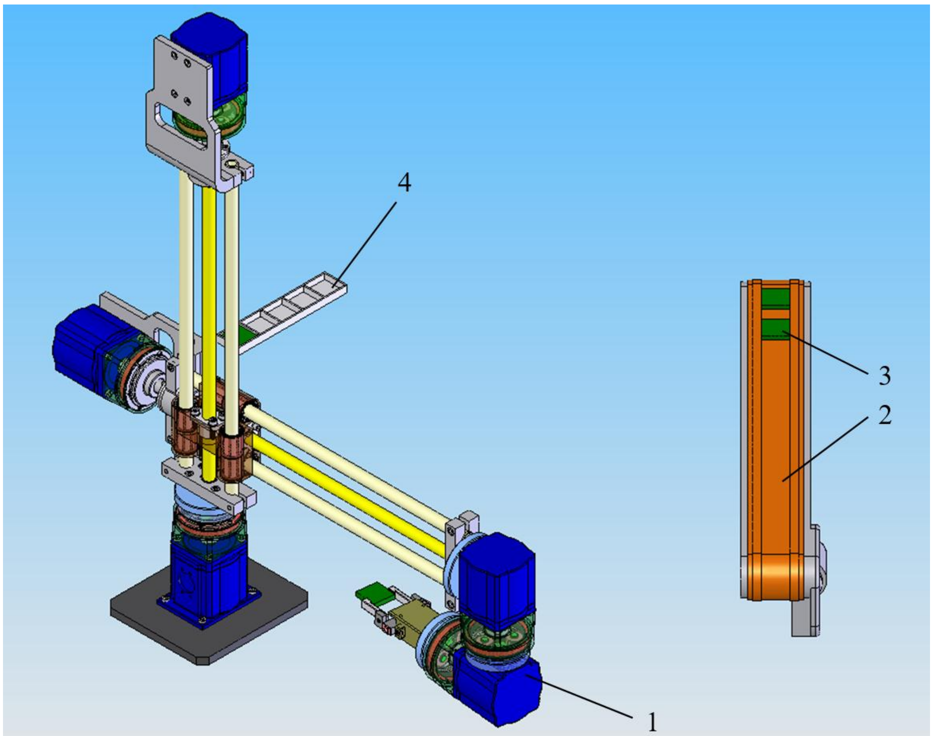

Figure 2. RTTRR small-sized industrial robot in a microprocessor packaging process

The figures 4 and 5 contain the following notations:

(0) – the robot zero configuration (nest position);

(1) – the configuration of part gripping, in the proximity of the conveyor;

(*i*) – the part release position in the compartment *i*, $i = 2 \ldots 6$.

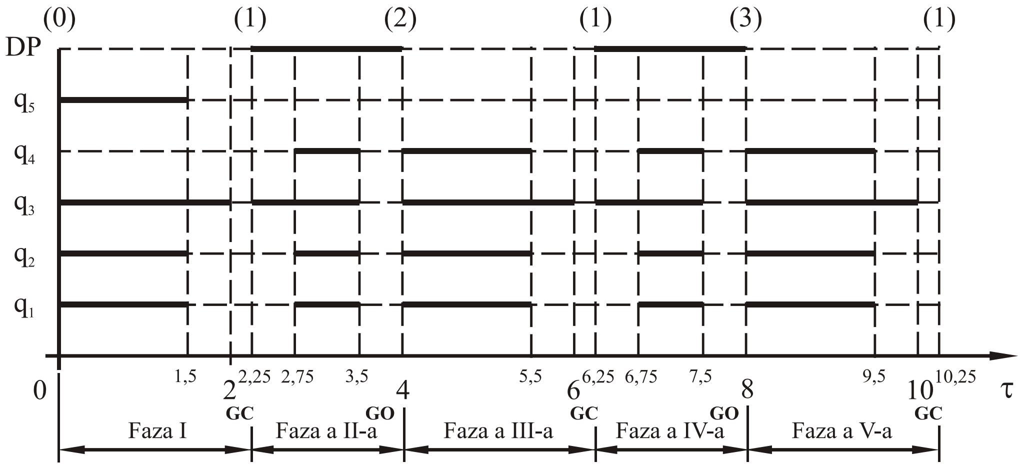

Figure 4. RTTRR robot operation cyclogram, phases I-V

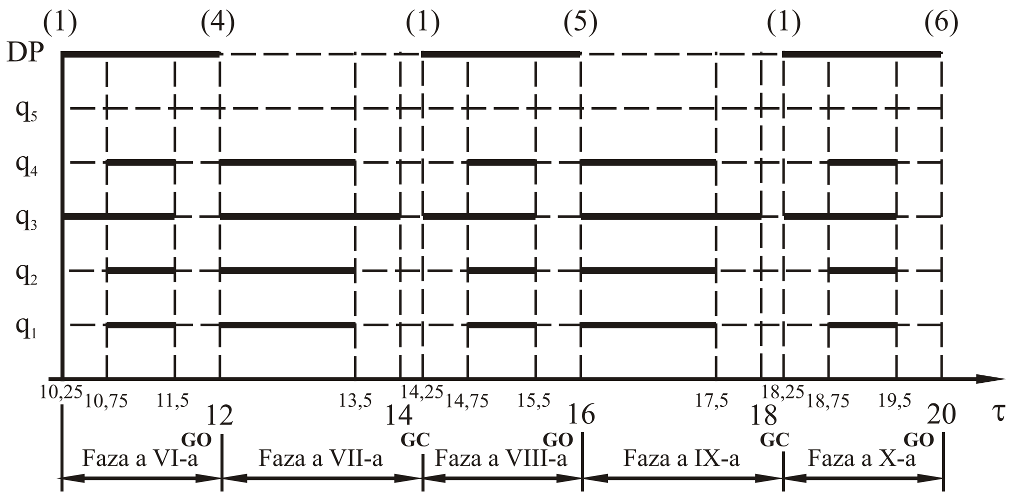

Figure 5. RTTRR robot operation cyclogram, phases VI-X

The gripper's (DP) state is marked with continuous line for loaded gripper and dashed line for free gripper. The part gripping phase was denoted by GC (Grip Closed), while the part releasing phase was denoted by GO (Grip Open). The joint operation periods were denoted by continuous line, corresponding to the analyzed time segments.

3 WORK PHASES DESCRIPTION

The work cycle of RTTRR robot is divided, as mentioned before, in ten phases, in order to achieve the planned technological process.

The robot moves, during *phase I*, from configuration (0) to configuration (1) and grips the microprocessor. The time interval dedicated to phase I is:

$$T_1 = 0...2.5\text{s} . \qquad (1)$$

The robot starts its motion from configuration (0) at the moment 0. In the interval of 0…1.5 s, the robot's joints make the following synchronous motions:

Joint 1 rotates the entire arm with:

$$\Delta q_1 = \pi/4 \text{ rad}, \qquad (2)$$

in order to position the robot on the conveyor direction.

Joint 2 makes a vertical translation with :

$$\Delta q_2 = 290 \text{ mm}, \qquad (3)$$

in order to raise the robot arm in the plane of the part to be gripped.

Joint 3 makes an arm lengthening with:

$$\Delta q_3 = 200 \text{ mm}, \qquad (4)$$

to reach the conveyor proximity. The motion is not continued, because of the rotation joints 1 and 5, which can produce a collision with the conveyor.

Joint 4 is stationary at this phase.

Joint 5 produces a rotation with:

$$\Delta q_5 = \pi/2 \text{ rad}, \qquad (5)$$

such that the gripper's fingers to get into the plane of the part to be transported.

The interval of 1.5…2 s is dedicated to the arm lengthening with:

$$\Delta q_3 = 90 \text{ mm}, \quad (6)$$

such that the gripper to reach the part position. All other joints are stationary. The robot reaches the configuration (1). In the interval of 2…2.25 s, the gripper's fingers are closed, the part is gripped, marking the end of the phase I.

During the *phase II*, the robot moves from the configuration (1) into configuration (2) and releases the part in the first compartment of the tray. The corresponding time interval is:

$$T_2 = 2.5...4\text{s}. \quad (7)$$

Starting from the configuration (1), having the part gripped in the gripper, during the interval of 2.25…2.75 s, the arm retracts with:

$$\Delta q_3 = -90 \text{ mm}, \quad (8)$$

in order to avoid the collision with the conveyor, before the base rotation. In the time interval of 2.75…3.5 s, the synchronized motions of the robot joints are the following:

Joint 1 rotates the entire arm with:

$$\Delta q_1 = \pi/4 \text{ rad}, \quad (9)$$

in order to position the arm in the vicinity of the partitioned tray.

Joint 2 makes the arm to lower with:

$$\Delta q_2 = -290 \text{ mm}, \quad (10)$$

in order to reach into the tray plane.

Joint 3 causes the arm retraction with:

$$\Delta q_3 = -180 \text{ mm}, \quad (11)$$

for the gripper positioning close to the first compartment of the tray (the closest to the joint 1 rotation axis).

Joint 4 rotates the gripper with:

$$\Delta q_4 = \pi/2 \text{ rad}, \quad (12)$$

in order to get the microprocessor right above the cell to be released in.

Joint 5 is stationary at this point. During this phase, the robot reaches configuration (2). Within the interval of 3.5…4 s, the fingers of the gripper are open and the part is released into the first compartment of the tray.

Table 1 presents the variation of the generalized coordinates corresponding to the first two phases. Within the other phases, the motion is similar, according to the data from the cyclograms and from the tables 2, 3, 4 and 5.

During the *phase III*, the robot returns from the configuration (2) into configuration (1) and catches the next microprocessor. The time interval allocated to phase III is:

$$T_3 = 4...6.25\text{s}. \quad (13)$$

Within the *phase IV*, the robot moves from the configuration (1) to the configuration (3) and releases the part into the second compartment of the tray. The corresponding time interval is:

$$T_4 = 6.25...8\text{s}. \quad (14)$$

Table 2 presents the variation of the generalized coordinates corresponding to the phases III and IV.

The *phase V* is dedicated to the robot returning from the configuration (3) to the configuration (1) and catching the part 3. The necessary time interval is:

$$T_5 = 8...10.25\text{s}. \quad (15)$$

During *phase VI*, the robot moves from the configuration (1) to the configuration (4) and releases the part 3 into the third compartment of the packaging tray. The corresponding time interval is:

$$T_6 = 10.25...12\text{s}. \quad (16)$$

Table 3 describes the variation of the generalized coordinates during the phases V and VI.

Within the *phase VII*, the robot returns from the configuration (4) to the configuration (1) and catches the fourth microprocessor, during the time interval:

$$T_7 = 12...14.25\text{s}. \quad (17)$$

The *phase VIII* is dedicated to robot displacement from the configuration (1) to the configuration (5) and releasing the fourth part into the fourth tray compartment. The time interval of this phase is:

$$T_8 = 14.25...16\text{s}. \quad (18)$$

Table 4 presents the generalized coordinates variation for the phases VII and VIII.

During phase IX, the robot returns from the configuration (5) to configuration (1) and catches the fifth part. The allocated time interval is:

$$T_9 = 16...18.25\text{s}. \quad (19)$$

The last useful phase (X) from the work cycle is necessary for the robot to move from the configuration (1) to the configuration (6) and to release the fifth part into the fifth compartment of the tray. The corresponding time interval is:

$$T_{10} = 18.25...20\text{s}. \quad (20)$$

Table 1. The variation of the generalized coordinates on path segments, phases I and II

	Phase I, t_{ij} [s]			**Phase II, t_{ij} [s]**		
Δq_j	0-1,5	1,5-2	2-2,25	2,25-2,75	2,75-3,5	3,5-4
Δq_1 [rad]	$\pi/4$	0	0	0	$\pi/4$	0
Δq_2 [mm]	290	0	0	0	-290	0
Δq_3 [mm]	200	90	0	-90	-180	0
Δq_4 [rad]	0	0	0	0	$\pi/2$	0
Δq_5 [rad]	$\pi/2$	0	0	0	0	0
G	-	-	GC	-	-	GO

Table 2. The variation of the generalized coordinates on path segments, phases III and IV

	Phase III, t_{ij} [s]			**Phase IV, t_{ij} [s]**		
Δq_j	4-5,5	5,5-6	6-6,25	6,25-6,75	6,75-7,5	7,5-8
Δq_1 [rad]	$-\pi/4$	0	0	0	$\pi/4$	0
Δq_2 [mm]	290	0	0	0	-290	0
Δq_3 [mm]	180	90	0	-90	-147,5	0
Δq_4 [rad]	$-\pi/2$	0	0	0	$\pi/2$	0
Δq_5 [rad]	0	0	0	0	0	0
DP	-	-	GC	-	-	GO

Table 3. The variation of the generalized coordinates on path segments, phases V and VI

	Phase V, t_{ij} [s]			**Phase VI, t_{ij} [s]**		
Δq_j	8-9,5	9,5-10	10-10,25	10,25-10,75	10,75-11,5	11,5-12
Δq_1 [rad]	$-\pi/4$	0	0	0	$\pi/4$	0
Δq_2 [mm]	290	0	0	0	-290	0
Δq_3 [mm]	147,5	90	0	-90	-115	0
Δq_4 [rad]	$-\pi/2$	0	0	0	$\pi/2$	0
Δq_5 [rad]	0	0	0	0	0	0
DP	-	-	GC	-	-	GO

Table 4. The variation of the generalized coordinates on path segments, phases VII and VIII

	Phase VII, t_{ij} [s]			**Phase VIII, t_{ij} [s]**		
Δq_j	12-13,5	13,5-14	14-14,25	14,25-14,75	14,75-15,5	15,5-16
Δq_1 [rad]	$-\pi/4$	0	0	0	$\pi/4$	0
Δq_2 [mm]	290	0	0	0	-290	0
Δq_3 [mm]	115	90	0	-90	-82,5	0
Δq_4 [rad]	$-\pi/2$	0	0	0	$\pi/2$	0
Δq_5 [rad]	0	0	0	0	0	0
DP	-	-	GC	-	-	GO

Table 5 presents the variation of the generalized coordinates on path segments, for the phases IX and X.

After finishing the phase X, depending on the application requirements, the work cycle can be resumed with returning to configuration (1), close to the conveyor, the tray being meanwhile replaced with an empty one, or the packing process can be ended, the robot returning to the configuration (0), the so called *nest position*.

Table 5. The variation of the generalized coordinates on path segments, phases IX and X

	Phase IX, t_{ij} [s]			Phase X, t_{ij} [s]		
Δq_j	16-17,5	17,5-18	18-18,25	18,25-18,75	18,75-19,5	19,5-20
Δq_1 [rad]	-π/4	0	0	0	π/4	0
Δq_2 [mm]	290	0	0	0	-290	0
Δq_3 [mm]	115	90	0	-90	-82,5	0
Δq_4 [rad]	-π/2	0	0	0	π/2	0
Δq_5 [rad]	0	0	0	0	0	0
DP	-	-	GC	-	-	GO

4 CONCLUDING REMARKS

The paper presents a possible implementation of the RTTRR small-sized industrial robot into a technological process of microprocessor packing. For this purpose, the work cycle was divided into ten work phases. Every phase was divided into three path segments, making possible the path modeling by (4-3-4) method of polynomial interpolation (Negrean, 2008).

As a future development of the paper, the interpolation functions for coordinates, velocities and accelerations for each path segments could be determined as a first stage, and then, using the geometric, kinematic and dynamic models, the simulation of the behavior of RTTRR small-sized robot can be done. Based on this simulation, some improvements regarding the work cycle of the robot can be figured out, such as: shortening the cycle period, pushing the velocities and accelerations up to the limit allowed by the actuation system, avoiding useless motions, and also changing the layout of the robotic cell in order to ensure the maximum efficiency for the robot.

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6 NOTATIONS

The following symbols are used in this paper:

T_i = time interval corresponding to the phase (i), i = 1…10;

t_{ii} = time interval corresponding to the phase (i) segments, i = 1…10, j = 1…3;

q_i = generalized coordinate from the joint i¸i= 1…5;

Δq_i = variation of the generalized coordinate (the displacement) from the joint i¸i= 1…5;

DP = gripper;

GO = gripper open;

GC = gripper closed;

RTTRR = in terms of robot joint type, R stands for *rotation*, T stands for *translation*.