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MINIMUM TIME MOTION PLANNING OF THE RTX ROBOT USING AN EVOLUTIONARY ALGORITHM

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Abstract

Minimum-time motion planning algorithm for an RTX robot is presented. Two methods are used for minimum-time trajectory planning over pre-specified paths. One of the methods considers kinematics constraints defined by the manufacturers, while the other method considers the full non-linear dynamic model of the robot. An evolutionary algorithm is used to determine the minimum-time paths. It is shown through simulation results that the later shows a significant improvement over the former in performance.

Introduction

RTX is a SCARA-type robot with six joints. The first joint is a prismatic one, and the other five joints are revolute. It is a low cost robot, and due to its simplicity, it has been the focus of a number of studies. Since it has been rated by the manufacturers to work on low speeds, most of these studies concentrate on the kinematics aspects and assume that complete non-linear dynamics are not significant. Song and De Keyser [16] have investigated the inverse kinematics of the RTX. Cao et al. [3-5] have proposed a minimum time motion planning algorithm for single and dual arm robotic work-cell for RTX robots. Dodds et al. [7] have proposed a multi-arm environment in which case studies for a dual-arm system have been presented. Temeltas and Asher [18] have presented a method for real-time identification of robot dynamic parameters using parallel processing. They have given the parameters for dynamic model for the first three joints of the RTX robot. An investigation is being presented for the application of algorithms proposed by the authors earlier [12,13] to the RTX robot. Motion planning for the first three joint variables of the RTX robot is compared for two trajectory planning algorithms. In the first algorithm, minimum time trajectories are planned subject to kinematics constraints given by the manufacturers. In the second algorithm, full dynamic model of the RTX is considered, and minimum time trajectories are planned subject to constraints on actuator force/ torques. An evolutionary algorithm is used to search for the time optimal path which uses time calculated through these two trajectory planning algorithms as the fitness function, and a comparison of simulation results is presented.

Simulation Results

Time-optimal collision free motion planning has been simulated for the case of static obstacles. Constraints on displacement of joint variables are also imposed. Table 1 gives the joint variable configurations for the different locations in the operational space of the RTX robot shown in Figure 4 (a) and (b). The limits on joint variable velocity and acceleration are used. Table 2 gives the optimal times planned between these configurations. The time-history of the joint variable displacement, velocity and acceleration are given in Figure 1 to Figure 3.

Table 1. Different configurations between which time-optimal collision-free motion was planned for the RTX robot.

	Zed d_1 (m)	Shoulder θ_2 (rad)	Elbow θ_3 (rad)	Yaw θ_4 (rad)	Pitch θ_5 (rad)	Roll θ_6 (rad)
①	0.5	$-\pi/4$	0	0	0	0
②	0.7	0	0	0	0	0
③	0.3	$\pi/4$	0	0	0	0

Table 2. Optimal time for the RTX robot to traverse between different configurations.

Motion	Time (sec)
①→②	2.3958
①→③	6.1667
②→③	4.6464

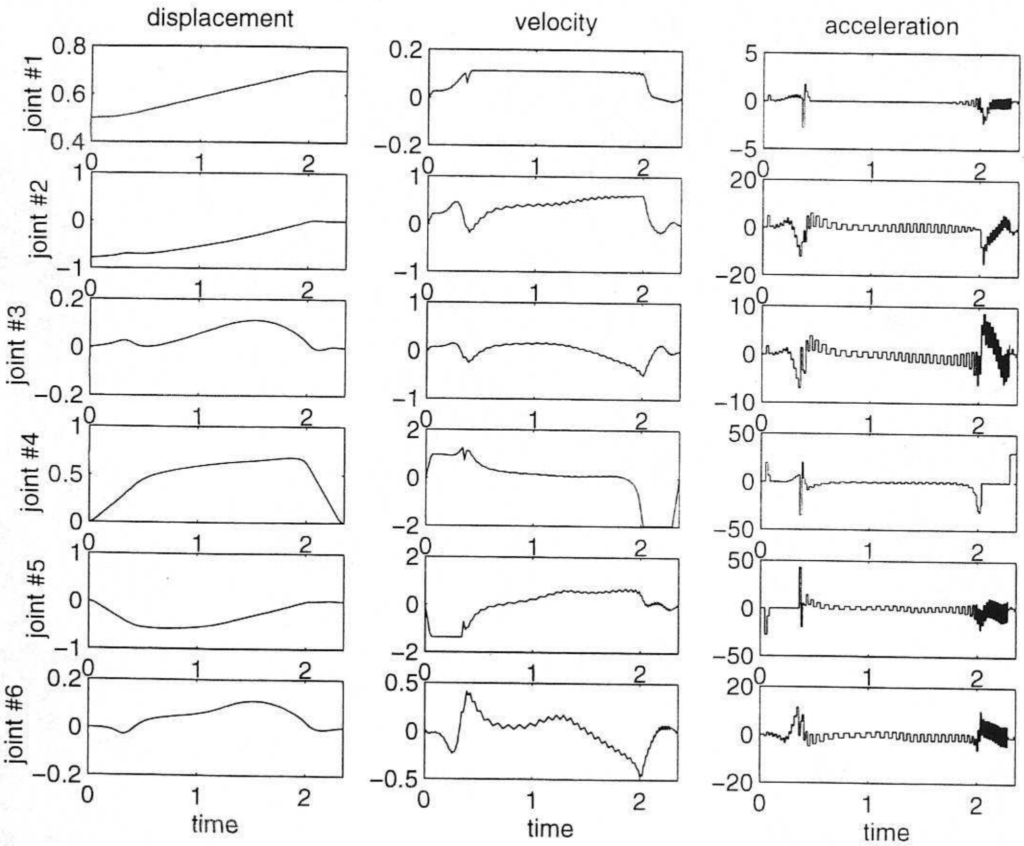

Figure 1. Collision-free minimum time motion for ①→②.

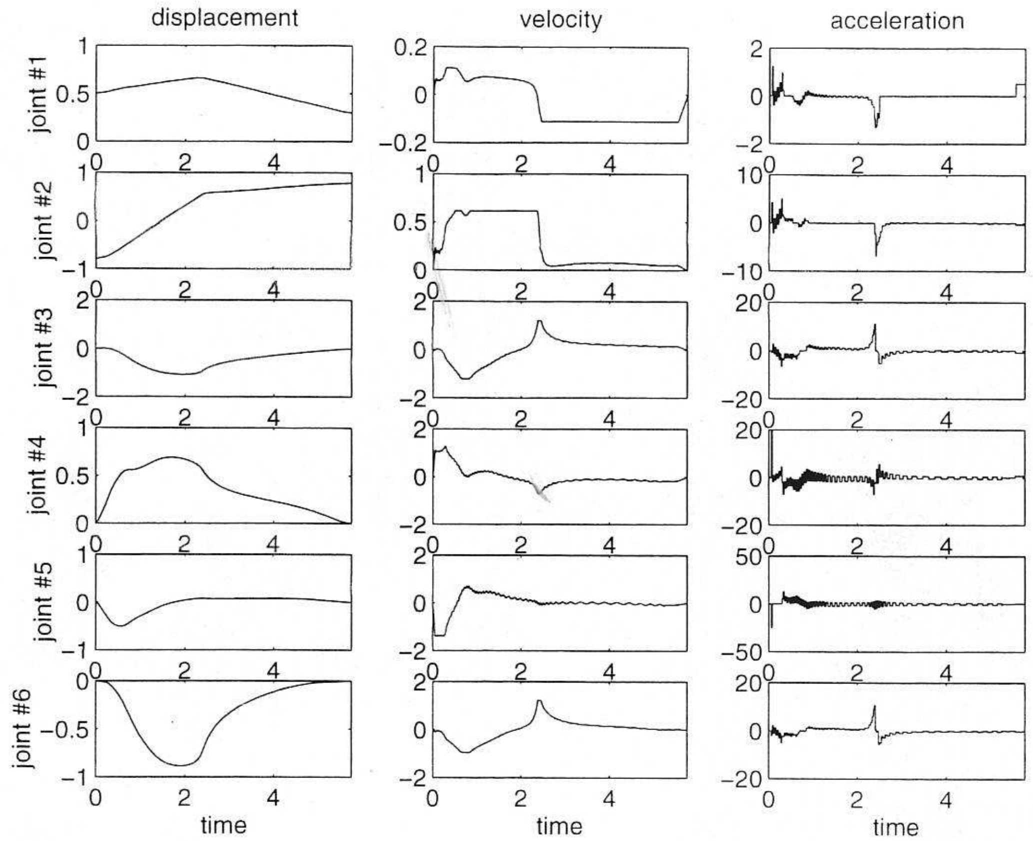

Figure 2. Collision-free minimum time motion for ①→③.

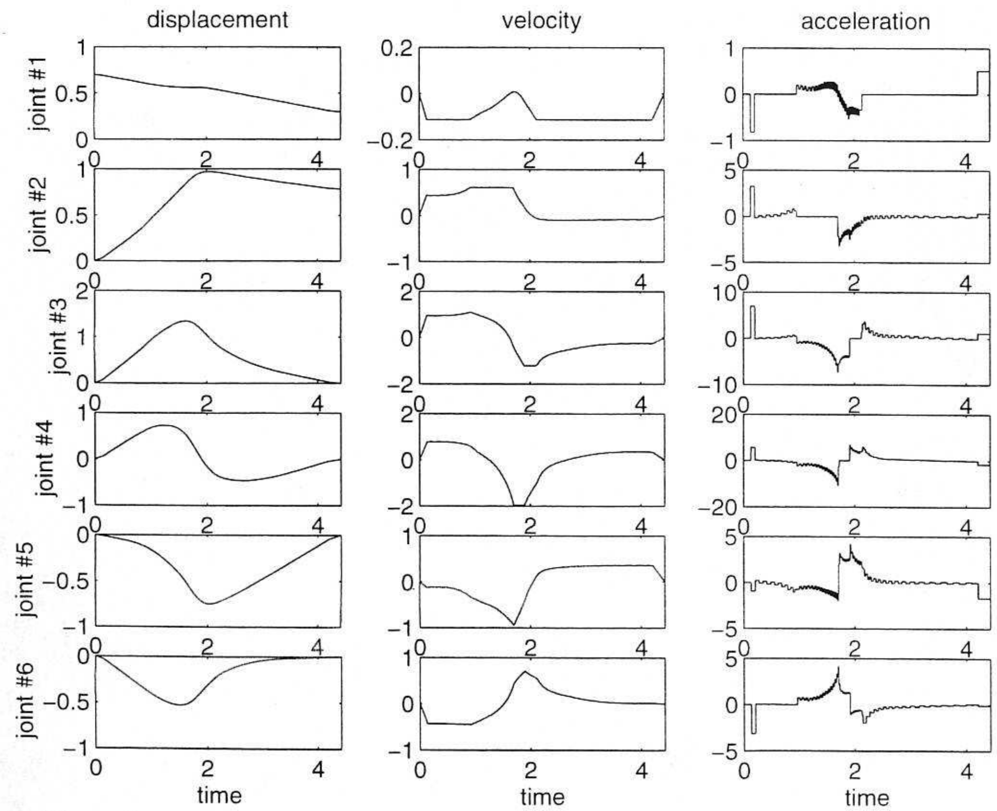

Figure 3. Collision-free minimum time motion for ②→③.

Simulation results are presented for the initial and final configurations given in Table 3. This example has been used by Cao et al. [3] for their algorithm, and is given here for the purpose of comparison. Path was then planned for the first three joints only for the same example. The results were compared with path planned by using the evolutionary planning algorithm, by using the dynamic model of the robot. The values of force/ torques used were ±40.00 N, ±1.5 N-m, ±0.5 N-m for joint #1, joint #2 and joint #3 respectively. The results are given in Table 4 and Figure 4 to 8.

Table 3. Initial and final configuration for the path planning of RTX robot.

	Zed d_1 (m)	Shoulder θ_2 (rad)	Elbow θ_3 (rad)	Yaw θ_4 (rad)	Pitch θ_5 (rad)	Roll θ_6 (rad)
Initial Configuration	0.4	$-\pi/6$	$-\pi/3$	$-\pi/2$	0	$-\pi/4$
Final Configuration	0.8	$\pi/6$	$\pi/3$	$\pi/2$	$-\pi/6$	$\pi/4$

Table 4. Results of the path planning algorithms.

Minimum time reported by Cao et al. [3] for motion of 6 joints of the RTX robot	3.856 sec.
Minimum time determined for the motion planned for 6 joints of the RTX robot by using GA planning with Kinematic constraints.	3.717 sec
Minimum time determined for the motion planned for the first 3 joints of the RTX robot by using GA planning with Kinematic constraints.	3.715 sec
Minimum time determined for the motion planned for the first 3 joints of the RTX robot by using GA planning with Dynamic constraints.	2.538 sec.

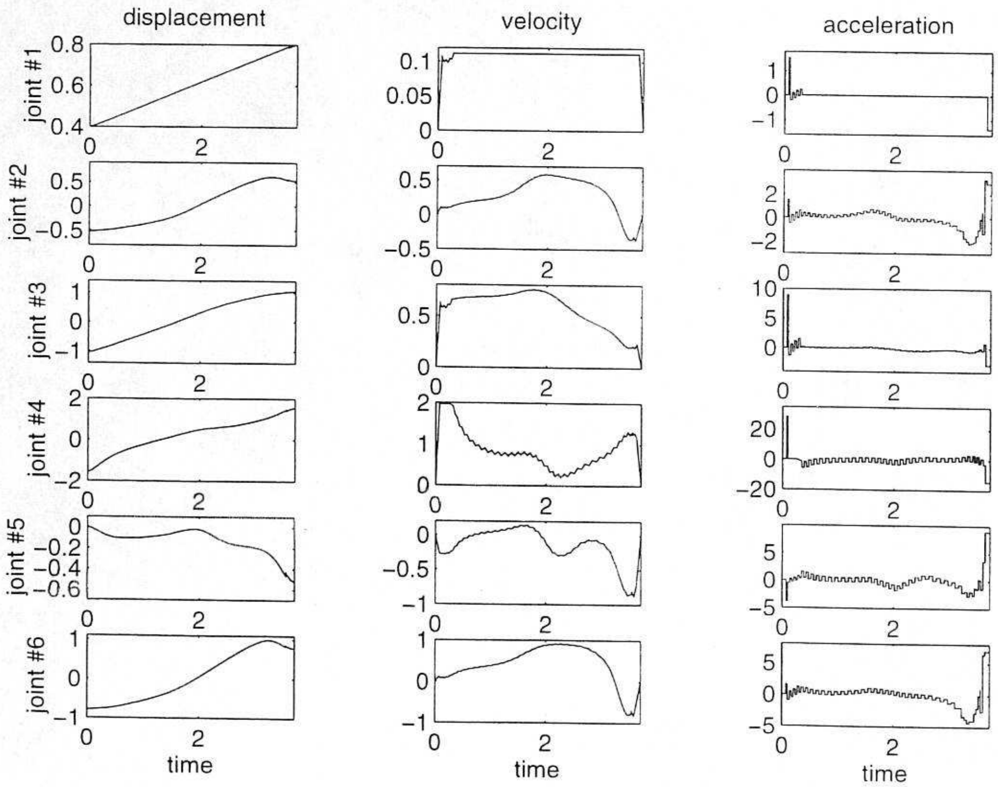

Figure 4. Profiles of displacement, velocity and acceleration in free space for all the six joint variables of the RTX robots by using trajectory planning method of section 6.1.

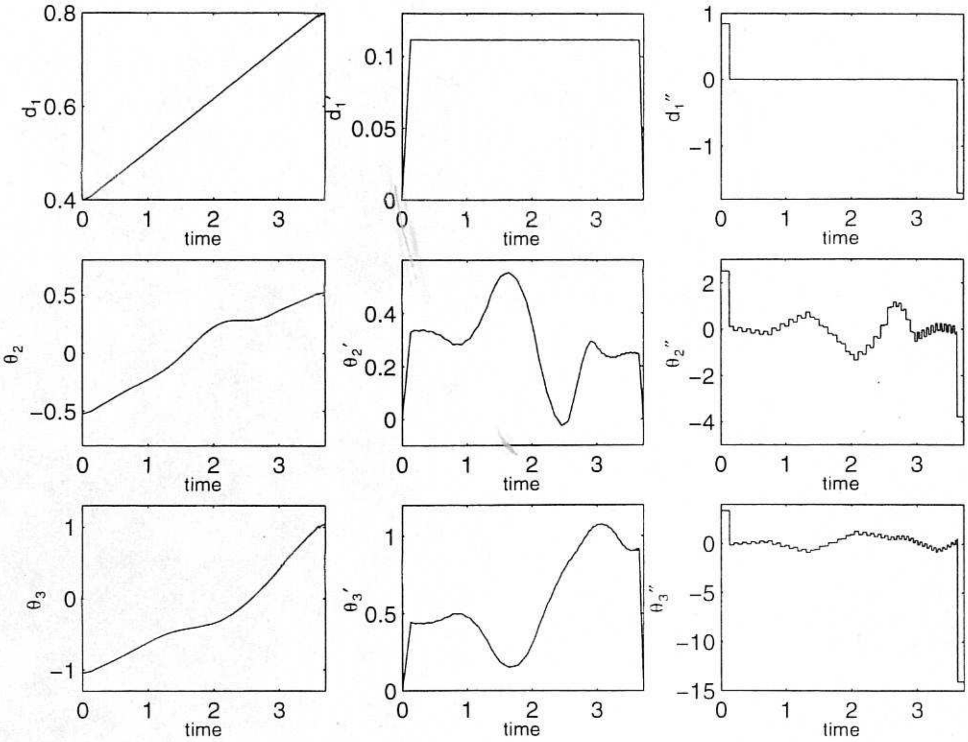

Figure 5. Profiles of displacement, velocity and acceleration in free space for the first three joint variables of the RTX robots by using trajectory planning method of section 6.1

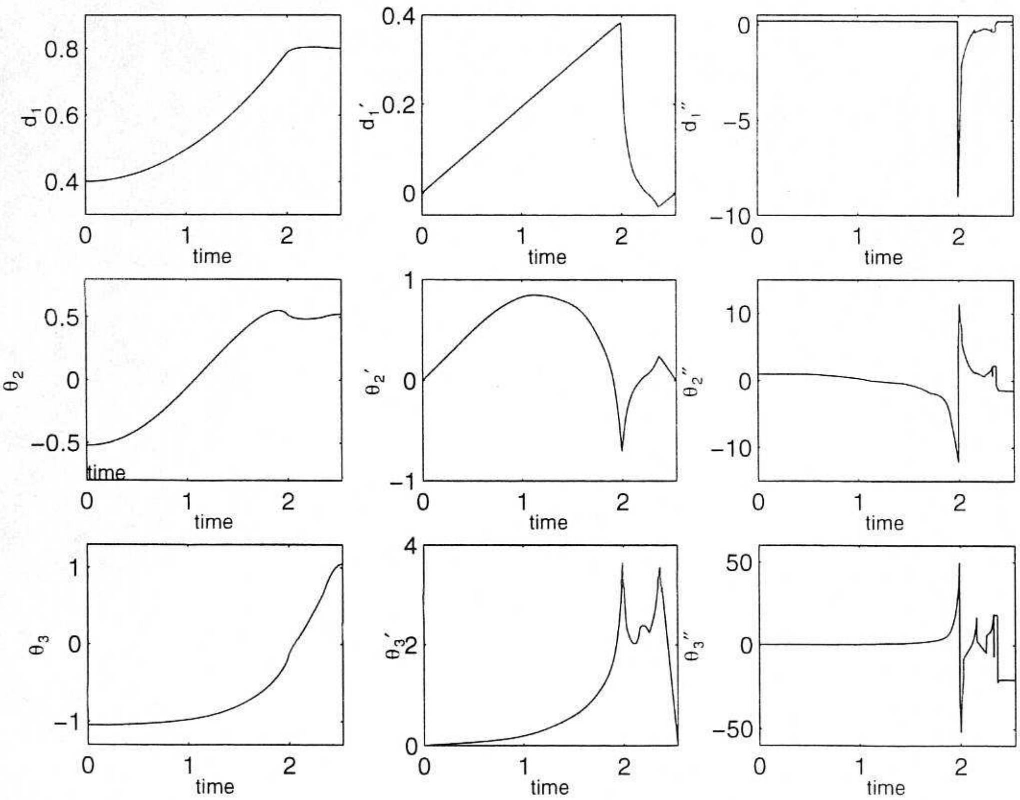

Figure 6. Profiles of displacement, velocity and acceleration in free space for the first three joint variables of the RTX robots by using trajectory planning method of section 6.2

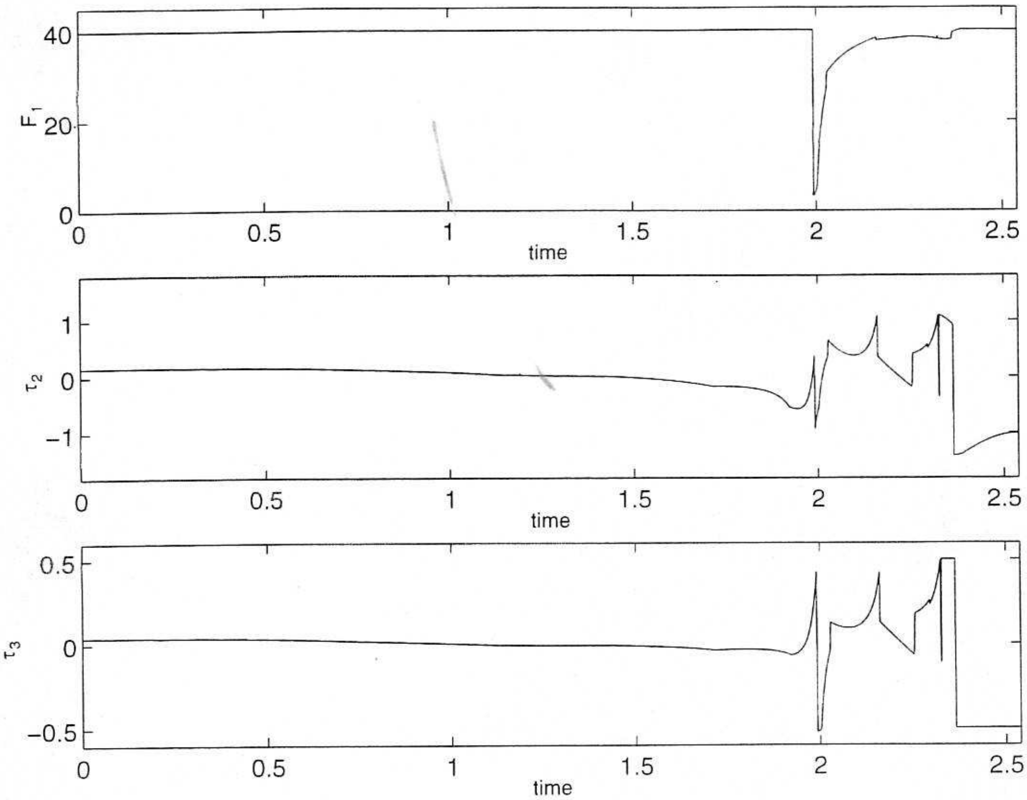

Figure 7. Profiles of the Force/ Torques for time-optimal motion of the first three joints of the RTX robot

Conclusions

A collision-free minimum time motion planning algorithm has been presented for an RTX-robot. Trajectory planning has been carried by using an algorithm which uses the concept of time-scaling based on the limits on velocity and acceleration given by the manufacturers. An evolutionary algorithm has been used to carry out the geometric path planning.

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