Optimizaton Of Robotic Manipulator For Drilling And Spot Welding Tasks

[1]**B. Vinayak**, [2]**G. Satish Babu**
[1]PG Scholar, MTech, Dept of Mechatronics, JNTUHCEH, Hyderabad, T.S.
Vinayakwin121@gmail.com
[2]Professor, Dept of Mechanical Engineering, JNTUHCEH, Hyderabad, T.S.

Abstract:
A minimum time path technique is proposed for multi points fabricating problems in drilling/spot welding tasks. By improving the traveling schedule of the set points and the exchange way between points, the base time assembling task is acknowledged under completely using the dynamic execution of mechanical controller. As per the start-stop movement in drilling/spot welding task, the path arranging issues can be changed over into a Travelling Salesman Problem (TSP) and a progression of point to point least time move way arranging problems. Cubic Hermite interpolation polynomial is utilized to parameterize the exchange way and afterward the way parameters are improved to secure least point to point transfer time. Another TSP with least time record is made by utilizing point-point move time as the TSP parameter. The traditional Genetic Algorithm (GA) is important to get the ideal traveling program. Some base time drilling tasks of a 3-DOF robotic manipulator are utilized as guides to exhibit the viability of the proposed methodology.

KEYWORDS: -Travelling Salesman Problem, Genetic Algorithm. Etc

I. INTRODUCTION: -

Robotic spot welding, a type of resistance welding, is the most common welding application found in the manufacturing field. It joins thin metals together when the metals resist the electrical current. While it is commonly used in the automotive industry to join sheet metal frames together, the spot welding application has a variety of project usesMinimum time motion planning problems for robotic manipulator were widely studied in industrial applications and several efficient solution methods are proposed. For the more broad least time point-to-point motion planning issue, the solution winds up complex since the way and the motion along the way should be upgraded at the same time. Different from the simplex motion planning issues as mentioned above, in assembling industry there exists a class of complex tasks called multi-points fabricating, for example, drilling , spot welding and get together . These tasks have numerous unordered points and henceforth it is important to design an optimal technique to navigate all the ideal points in a deliberate manner while fulfilling the necessity of least separation, least time or least energy, and so forth.

So as to streamline the issue, the common way planning systems for multipoints assembling expect the exchange way between any two points is straight line, and the issue can be portrayed as a TSP with least separation list. Anyway as per Bobrow [3] and Dubowsky and Blubaugh [4], it is indicated that because of the nonlinear expressions of the controller dynamics and gravitational torques, it is non-proportionate between the base time way and the base separation way, even the base time way from guide I toward point j is additionally unique in relation to the direct j toward point I way. Thus other than the optimization of voyaging calendar of the set points, the exchange ways between machining points additionally should be advanced to acquire the base exchange time. In this paper, the base time way planning issue for multi points assembling is contemplated. Since the sightseeing timetable of the set points and the itemized exchange way between points must be upgraded all the while, a blended number optimal control formulation is constructed to depict the issue. In light of the beginning stop development in drilling/spot welding task, the issue can be further converted in to an unadulterated whole number straight programming issue and a progression of point to point least time move way planning issues. In this paper, a common hereditary algorithm (GA) is applied to fathom the produced whole number straight programming issue. What's more, cubic Hermite interpolation polynomial is utilized to parameterize the exchange way and afterward the way parameters are upgraded to acquire least point to point move time.

II. Problem Illustration: -

In pragmatic applications, the 6-DOF robotic manipulator is typically required to acquire the free position and direction yield of the end effector. The regular setup of a 6-DOF manipulator is that the initial three joints are utilized to find the situation of the end effector and the last three joints understand the direction change through collaboration. In this paper, we centre around the position optimization at each time and the effector direction can be determined consequently as indicated by the manufacturing necessity. Thus, just the initial three joints of manipulator are talked about here. The elements model of robotic manipulator with initial three joints can be defined

$$\boldsymbol{\tau} = \mathbf{K}(\mathbf{q})\ddot{\mathbf{q}} + \dot{\mathbf{q}}^{\mathbf{T}}\mathbf{B}(\mathbf{q})\dot{\mathbf{q}} + \mathbf{F}(\mathbf{q}) \qquad \mathbf{a}$$

where $\mathbf{q} \in \mathbf{R}^{\mathbf{n}}$ denotes the vector of joint angular position, $\boldsymbol{\tau} \in \mathbf{R}^{\mathbf{n}}$ denotes the vector of joint toques, $\mathbf{K}(\mathbf{q}) \in \mathbf{R}^{\mathbf{nxn}}$ is the inertia matrix of manipulator which is symmetric in which the diagonal elements $\mathbf{K}(j,j)$ describe the inertia seen by joint j and the off-diagonal elements $\mathbf{K}(i,j)$ represent coupling of acceleration from joint j to the generalized force on joint i, $\mathbf{B}(\mathbf{q}) \in \mathbf{R}^{\mathbf{nxn}}$ contains the information of centrifugal and Coriolis forces in which the centripetal torques are proportional to $\dot{\mathbf{q}}^{\mathbf{2}}(\boldsymbol{i})$ while the Coriolis torques are proportional to $\dot{\boldsymbol{q}}(\boldsymbol{i})\dot{\boldsymbol{q}}(\boldsymbol{j})$, $\mathbf{F}(\mathbf{q}) \in \mathbf{R}^{\mathbf{n}}$ is the vector of gravity-induced torques which always exists even when the robot is stationary or moving slowly, n = 3. The objective of this paper is to plan a reasonable course along which the controller depletes all the given concentrates just by once while the task time is least under the components furthest reaches of the controller. Allow nc to mean the amount of the task points. Define z_1; z_2;⋯; z_{nc} as the effector positions in task space corresponding to the n_c drilling points and $\mathbf{z_i} \in \mathbf{R}^{\mathbf{3}}$. The motion performance of each joint is restricted by the torque constraint,

$$-\boldsymbol{\tau_b} \leq \boldsymbol{\tau} \leq \boldsymbol{\tau_b} \qquad \mathbf{b}$$

And the joint velocity constraint,

$$-\dot{\boldsymbol{q}}_{\boldsymbol{b}} \leq \dot{\boldsymbol{q}} \leq \dot{\boldsymbol{q}}_{\boldsymbol{b}} \qquad \mathbf{c}$$

where the joint velocity satisfies $\dot{\boldsymbol{z}} = \boldsymbol{J}(\boldsymbol{q})\dot{\boldsymbol{q}}$ and $\mathbf{J(q)}$ denotes the Jacobian matrix of the forward kinematics map. Since the end effector need keep still during the drilling/ spot welding process, then we have $\dot{\boldsymbol{q}}_{\mathbf{i}}$ =0 corresponding to the ith point position $\mathbf{z_i}$ in task space with i =1; 2;⋯; n_c. Most importantly, the ideal least time way planning issue for penetrating/spot welding errands has the accompanying definition.

min $q_t T_f$

$$q_{i=} QW_i$$

$$\dot{q}_i = 0, \ \ i = 1,2, \dots, n_c$$

$$\sum_{i=1}^{n_c} W_i = [1,1 \dots, 1]^T_{n_c}$$

$$\boldsymbol{\tau} = \mathbf{K}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{B}(\mathbf{q},\dot{\mathbf{q}})\dot{\mathbf{q}} + \mathbf{F}(\mathbf{q}) \qquad \mathbf{d}$$

(3.4)

$$-\boldsymbol{\tau_b} \leq \boldsymbol{\tau} \leq \boldsymbol{\tau_b}, -\dot{\boldsymbol{q}}_{\boldsymbol{b}} \leq \dot{\boldsymbol{q}} \leq \dot{\boldsymbol{q}}_{\boldsymbol{b}}$$

$$\boldsymbol{q} \in \Omega q$$

where, Q = $[q_1, q_2, \cdots, q_{nc}]_{nxnc}$ contains all the joint positions of task points, and $\dot{\mathbf{q}}_{\mathrm{i}}$ denotes the joint velocity at the ith task position, $\boldsymbol{W} \in \boldsymbol{R}^{\boldsymbol{n_c} \,\mathbf{x}\, \boldsymbol{n_c}}$ act as a enable switch to ensure the manipulator pass all the given points only by once, $\mathbf{W_i} \in \{\mathbf{0,1}\}^{\mathbf{nc}}$; is a n_c-dimension column vector, Ωq denotes the geometry constraint of the joint position,0= $t_1 < t_2 < \cdots < t_{nc} = T_f$.

Problem (d) is a typical mixed integer optimal control problem. Similar to Dubowsky and Blubaugh, since the motion velocity of each joint need drop to zero at the task point, Problem (d) can actually be decomposed into a minimum time TSP and a series of point to point minimum time path planning sub problem with only continuous variables. In this paper, each point to point path planning subproblem is solved by a direct parameterization approach to obtain minimum transfer time Tij, the n minimum time TSP is processed and evaluated by a specific genetic algorithm (GA).

III Subproblem solution-Obtain transfer path and Tij: -

The minimum time path planning subproblem from point qi to qj can be formulated as

Min q(t) T_{ij}

$$\boldsymbol{\tau} = \mathbf{K}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{B}(\mathbf{q},\dot{\mathbf{q}})\dot{\mathbf{q}} + \mathbf{F}(\mathbf{q}),$$

$$-\boldsymbol{\tau_b} \leq \boldsymbol{\tau} \leq \boldsymbol{\tau_b}, -\dot{\boldsymbol{q}}_{\boldsymbol{b}} \leq \dot{\boldsymbol{q}} \leq \dot{\boldsymbol{q}}_{\boldsymbol{b}},$$

$\dot{\boldsymbol{q}}(0) = 0, \dot{\boldsymbol{q}}(T_{ij}) = 0,$ **e**

$\boldsymbol{q}(0) = \boldsymbol{q_i}, \boldsymbol{q}(T_{ij}) = \boldsymbol{q_j}$
(3.5)

$\boldsymbol{q}\epsilon\Omega$q.

So as to create smooth transfer way, the cubic Hermite polynomial is applied to approximate the path. Define path parameter as sϵ[0,1], the parametric path from point i to point j can be described as

q(s)= h_{00}(s)$\mathbf{q}_i$+h_{10}(s)$\mathbf{r_i}$+h_{01}(s)$\mathbf{q_j}$+ h_{11} (s) $\mathbf{r}_j$, sϵ[0,1]**f**

where $\mathbf{r_i}$ denotes the initial slope of the path and $\mathbf{r_j}$ denotes the final slope. The Hermite bases in (f) are

$h_{00} = 2s^3 - 3s^2 + 1,$

$h_{01} = - 2s^3 + 3s^2$

$h_{10} = s^3 – 2s^2 + s$

$h_{11} = s^3 – s^2.$

Then the gradient information of the path w.r.t parameter s is

$\boldsymbol{q}'(s) = \frac{\boldsymbol{dq}}{\boldsymbol{ds}} = h'_{00}(s)p_i + h'_{10}(s)\boldsymbol{r_i} + h'_{01}(s)\boldsymbol{p_j} + h'_{11}(s)\boldsymbol{r}_j,$ **g**

$\boldsymbol{q}''(s) = \frac{\boldsymbol{d^2q}}{\boldsymbol{d^2s}} = h''_{00}(s)p_i + h''_{10}(s)\boldsymbol{r_i} + h''_{01}(s)\boldsymbol{p_j} + h''_{11}(s)\boldsymbol{r}_j,$ **h**

The joint velocity can be equivalent to

$\dot{\boldsymbol{q}}(t) = \boldsymbol{q}'(s(t))\dot{s}(t)$ **i**

The joint torque becomes

$\boldsymbol{\tau} = \boldsymbol{m}(s)\ddot{s} + \boldsymbol{c}(s)\dot{s}^2 + \boldsymbol{g}(s)$ **j**

where,.

m(s) = **K**(**q**(s))**q**'(s) $\boldsymbol{\epsilon R^n}$, **c**(s) = **K**(**q**(s))**q**''(s) + **B**(**q**(s),**q**'(s))**q**'(s)) $\boldsymbol{\epsilon R^n}$, **g**(s) = **F**(**q**(s))) $\boldsymbol{\epsilon R^n}$**.**

Hence, the variables, which need to be optimized in problem (e), are the path slopes r_i; r_j and the parameter acceleration variable $\ddot{s}(t)$. Define new variables a= $\dot{s}^2$and b= $\ddot{s}$. Define path variable u= [$\boldsymbol{r_i^T}$, $\boldsymbol{r_j^T}]^{\boldsymbol{T}}$ then problem (e) can be rewritten as the following optimal control problem in parameter space.

min(u,b) $T_{ij} = \int_0^1 \frac{1}{\sqrt{a}} ds$

$\boldsymbol{\tau}(\boldsymbol{s}) = \mathbf{m}(\mathrm{u,s})\mathrm{b} + \mathrm{c}(\mathrm{u,s})\mathrm{a} + \mathrm{a}(\mathrm{u,s}),$

$-\boldsymbol{\tau_b} \leq \boldsymbol{\tau}(\boldsymbol{s}) \leq \boldsymbol{\tau_b}, -\dot{\boldsymbol{q}}_{\boldsymbol{b}} \leq \boldsymbol{q}'(u,s)\sqrt{a} \leq \dot{\boldsymbol{q}}_{\boldsymbol{b}}$

$\dot{\boldsymbol{q}}(u,0) = 0, \dot{\boldsymbol{q}}(u,1) = 0,$ **k**

$\boldsymbol{q}(\boldsymbol{u},\boldsymbol{s})\epsilon\Omega$q
variable u and there is no explicit correlation between the optimizing objective and the path variable u. On the other hand, we can see the motion variables (a, b) are linear in constraint functions of problem (k) and convex in the optimizing objective. Assume the path variable u is fixed in problem (k), then a convex optimization solution can be realized since problem (k) has a convex optimal problem formula at this time. So, for each variable **u** corresponding to any feasible non-singular path, there exists a uniqueoptimal variable pair (a^*, b^*) and unique minimum transfer time Tij^*.

Then the minimum time point to point path planning problem can be again described as the following optimization problem.

min u (Tij^*),s.t **q**(**u**,s) $\boldsymbol{\epsilon}$ Ωq.**l**
SQP, BFGS, et al.

IV The study of path points: -
Here, a drilling task in Y-Z plane is studied to verify the effectiveness of the proposed method. In which it has three parts as follows;

1) Which is to verify the effectiveness of the point-point minimum time transfer path planning,
2) This part is to test the optimization of the minimal operation time schedule differentiate with the minimal travel distance schedule and the minimal angular travel schedule.
3) The last part is to test the practicability of the proposed algorithm by using a 100 points task.

A3-DOF manipulator as shown in Fig. 3.2 is applied in this test and the torque bounds of all three joints are set as [140;140;50] N.m.

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 11
October 2019

The Y-Z work plane is placed at x=1 m ahead of the robot base and the way geometry limitation is set as no impedance between the work plane and the robot end effector. Eight drilling points are placed inY-Z plane as shown in Fig.1.In light of reverse kinematics calculation, the joint positions of robot corresponding to each drilling points can be additionally determined.

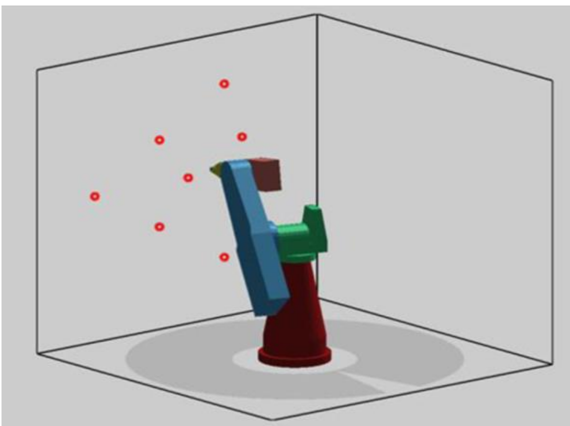

Fig 1. The robot used in drilling process

V Minimum time traversal test for multi task points: -

We can obtain the elements of measurement matrix A for the minimal operation time method. Also, the measurement matrixes of the minimal travel distance method and the minimal angular travel method can be calculated conveniently. As shown in Fig. 2, the travelling schedules of the three methods are different. Here were cord the test data and list them as follows.

(a). The travelling schedule of the minimal travel distance method is7-6-5-3-2-1-4-8-7, and the related path length is 5.512 m, total angular travel distance is 10.974 rad, total motion time is 2.98s. The length of each transfer path is 0.549 m-0.549 m -0.847m -0.509m -0.82 m -0.7 m -0.82 m -0.555 m. And the corresponding minimum transfer time is 0.43s -0.38s -0.48s -0.33s -0.43s -0.42s -0.41s -0.40s.

(b). The travelling schedule of the minimal angular travel method is 7-6-5-2-1-4-3-8-7, and the related path length is 5.498 m, total angular travel distance is 9.875rad, total motion time is 3.257s. The length of each transfer path is 0.564m -0.563 m -0.855m -0.827 m -0.827 m -0.527 m -0.874 m -0.557m. And the corresponding minimum transfer time is 0.440s -0.41s -0.43 -0.41s -0.42s -0.36s -0.47s -0.39s.

(c). The travelling schedule of the minimal operation time method is 5-6-3-7-8-4-1-2-5, and the related motion time is 2.978s, path length is 6.001m, total angular travel distance is 11.125 rad. The motion time of each transfer path is 0.35s -0.34s -0.35s -0.38s -0.39s -0.41s -0.41s -0.38s. And corresponding length of transfer path is 0.568m -0.678m -0.645m -0.565 m -0.829 m -0.835 m -0.836m -0.852 m. In this test, the path length of minimum time motion is 7.2% longer than that of the minimum distance motion. And the total angular travel distance of minimum time motion is 22.4% larger than of the minimum angular travel motion. However, the related optimal motion time of the proposed method reduces 5.5% compared with the minimal travel distance method and 8.1% compared with the minimal angular travel method.

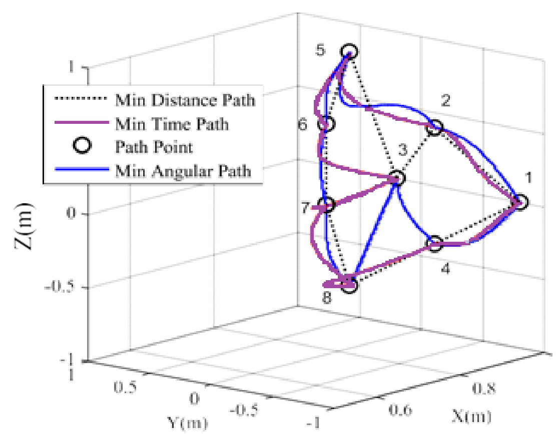

Fig 2.Optimized paths for the minimal operation time method, least travel distance method and the least angular travel method.

VI Practicability test: -

In this section, the practicability of the proposed algorithm is tested by execute a series of drilling tasks with 10,25,50 and 100 points, respectively. The task points are shown in Fig.3.The performance comparison between the minimal operation time method, minimal travel distance method and the minimal angular travel method is listed in Table 1. According to Table 4.1, though the travel distance and angular displacement of the minimal operation time method is large than the other two methods, the operation time is obviously shorter than them. Fig. 4. shows the operation time improvement of our method compared with the minimal travel distance method and the minimal angular travel method. According to

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 11
October 2019

Tests	Computation time (H: MIN:S)		
	Our Algorithm	Min Distance	MinAngular
10 points	00:02:34	00:00:14	00:01:45
25 points	00:15:08	00:00:34	00:12:34
50 points	01:19:23	00:02:08	00:49:59
100 points	02:52:59	00:10:58	01:44:58

the test results of the four examples, the proposed algorithm can improve the productivity about 8%~56% compared with the existing algorithms.

Table 1.Computational cost comparison among the three methods.

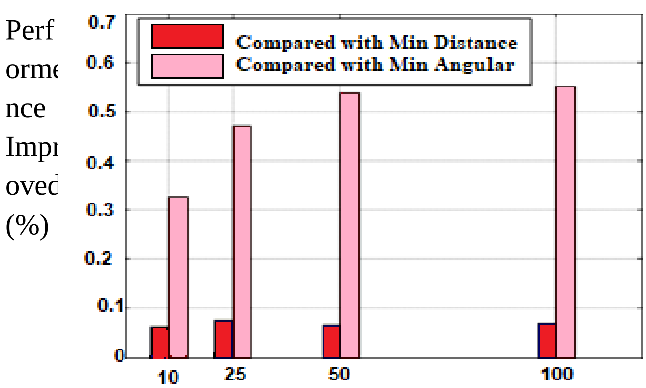

Fig 4. Performance improvement compared with the minimal travel distance method and the minimal angular travel method

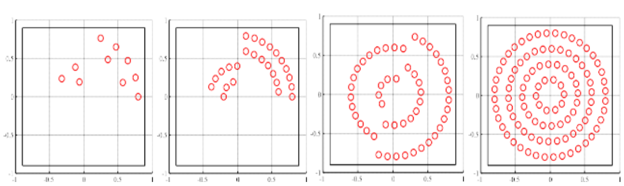

Fig. 3. Test examples (From left, 10 points, 25 points, 50 points, 100 points).

The theoretical analysis of the algorithm complexity is not concerned in this paper. Yet by using the test results, we can check the algorithm complexity. From the test results, we can see that the presented algorithm is time consuming. This is because a large number of optimizations subprocesses must be executed to calculate the minimum time transfer paths in the proposed algorithm. However, since the algorithm is executed offline, we think the computational cost of the proposed method can be acceptable. Finally, we draw the time optimal travelling path for the 100 points tasks.

VII Conclusion: -

In this paper, a minimum time planning technique is proposed for multi focuses manufacturing issue in drilling/spot welding task. Inside the cutoff points of manipulator elements performance, the minimum time path is gotten by improving the sightseeing schedule of the set points and the detailed transfer path between points simultaneously. This technique depends on GAs and the primary advancement is made on the encoding of the GA so as to think about the various arrangements of the converse kinematics issue for the calculation of the all-out process duration. In our methodology, the chromosome comprises of two sections.Furthermore, the encoding of the proposed GA could be applied in comparative issues, where there is a limited number of approaches to arrive at a point or to move from point to point.

VIIIReferences: -

[1] Zhang Q, Li S R. Efficient Computation of Smooth Minimum Time Trajectory for CNC Machining. Int J Adv ManufTechnol 2013;68(1-4) 683–92.

[2] Zhang Q, Li S R, Gao X S. Practical smooth minimum time trajectory planning for path following Robotic manipulators. Am Control Conf, USA, Jun 2013:17–9.

[3] Bobrow JE, Dubowsky S, GibsonJS. Time-Optimal Control of Robotic Manipulators Along Specified Paths. Int JRobotRes 1985;4(3)3–17.

[4] Zhang K, Gao X S,Li H B, Yuan C M . A Greedy Algorithm for Feed-rate Planning of CNC Machines along Curved Tool Paths with Confined Jerk for Each Axis. Robot ComputIntegrManuf 2012;28:472–83.

[5] Bobrow J. Optimal robot path planning using the minimum time criterion. IEEE J Robot Autom 1988;4(4)443–50..

[6] Erkorkmaz K, Alzaydi A, Elfizy A, EnginS. Time-optimal trajectory generation for5-axis on-the-fly laser drilling. CIRP Ann-ManufTechnol2011;60:411–4.

[7] Erkorkmaz K, Alzaydi A, Elfizy A, EnginS.Time-optimized hole sequence planning for5-axison-the-fly

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 06 Issue 11
October 2019

laser drilling. CIRP Ann-ManufTechnol2014;63:377–80.

[8] Huang T, Wang P F, Mei J P, Zhao X M, Chetwynd D G. Time Minimum Trajectory Planning of a 2-DOF Translational Parallel Robot for Pick-and-Place Operations. CIRP Ann-ManufTechnol 2007;56(1)365–8.

[9] Dubowsky S, Blubaugh T D. Planning time-optimal robtic manipulator motions and work places for point to point tasks. IEEE Trans Robot Autom 1989;5(3)337–81.

[10] Petiot J F, Chedmail P, Hascoet J Y. Contribution to the scheduling of trajectories in robotics. Robot Comput-IntegrManuf1998;14:237–51.

[11] Th Zacharia P, Aspragathos N A. Optimal robot task schedulng based on genetic algorithms. Robot Comput-IntegrManuf2005;21:67–79.