Research on Trajectory Planning of 6Rs Palletizing Robot Based on Adaptive Genetic Algorithm

Haibo Lin, Lida Yang [a]

Automatization Engineering College, Chongqing University of Posts and Telecommunications, Chongqing 400065 China;

[a]454086567@qq.com

Abstract

In the design of tobacco palletizing robots, aiming at the disadvantage of online teaching reproduction programming affected greatly by the uncertain factors ,the palletizing process was simulated using V-rep software. Based on the structural parameters of FANUC ARC 100 i-type industrial robot and D-H theory, the kinematic equations of the robot are deduced, Cubic B-spline curve fitting method makes robot trajectory more smooth, in order to achieve the optimal trajectory planning time for the purpose, using adaptive genetic algorithm to optimize the trajectory of palletizing robot for the shortest time, and use Matlba to realize trajectory planning simulation.

Keywords

Palletizing robot; V-rep; Adaptive Genetic Algorithm; Matlab.

1. Introduction

The palletizing robot can replace the artificial high precision and high precision duplication of boring processing, and has a broad application and development prospects, trajectory planning is an important research direction in the research of palletizing robot. The trajectory planning of the palletizing robot refers to the optimal trajectory design in the case of satisfying the related kinematic and dynamic constraints. Document [2] gives the time optimal trajectory planning, which is also the most common optimization method， it can accomplish the specified tasks in the shortest time and improve the efficiency of the industrial robot. But this method will have a great impact and shorten the service life of the industrial robot. In document [3], the 3-5-3 spline function is proposed for the trajectory planning of the robot, thus effectively avoiding the vibration of acceleration.

The trajectory planning of the palletizing robot needs to meet certain kinematic and dynamic constraints, which requires the handling of the constrained optimization problem. Document [4] uses PSO algorithm to plan the time optimal trajectory of space robot under dynamic constraints. In document [5], the penalty function method is combined with the standard genetic algorithm to solve the constraint problem effectively. However, the standard genetic algorithm has low convergence speed and poor global search ability. Therefore[6] proposed a new improved adaptive genetic algorithm, which greatly improved the performance of the algorithm.

In this paper, the V-rep software is used to simulate the palletizing process; Using three B spline fitting in the joint space of the palletizing robot trajectory, the trajectory is optimized by adaptive genetic algorithm, the palletizing robot in the shortest time to a predetermined position according to a predetermined trajectory, so as to achieve the shortest time trajectory planning, finally through the simulation of Matlab, the feasibility and reliability of trajectory planning the verification.

2. Simulation of palletizing process

2.1 Palletizing simulation platform V-rep

In this paper, V-rep is chosen as a simulation platform for palletizing robot. V-rep is called the Swiss Army knife in the field of robot simulation. It integrates modeling, programming, physics engine and so on, and is compiled by Lua script language. The main characteristics of V-rep in simulation control include distributed control, convenient model browser, sensor simulation, dynamics and physics, dynamic particle, path planning, complete interaction and other [7].

2.2 Construction of palletizing platform

In this paper, the palletizing robot is mainly aimed at the grasping and placing operation of irregular smoke packets, there are 25 types of smoke packets from the heat shrinkable furnace to the transmission machine, and 1-25 are different, each cigarette packet has a maximum of five layers, each layer of up to five, each type can exist separately, and its intention is shown in Figure 1.

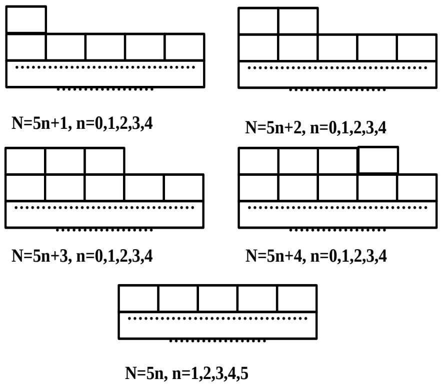


Fig.1 Irregular packet virtual modeling

2.3 Virtual modeling of industrial robot

A six degree of freedom industrial robot will be selected for the irregular stack of smoke bags. In the Model browser directory of the V-rep software main interface, the robots module is brought with you, and the robot in the main interface is dragged to the main interface as shown in the diagram.

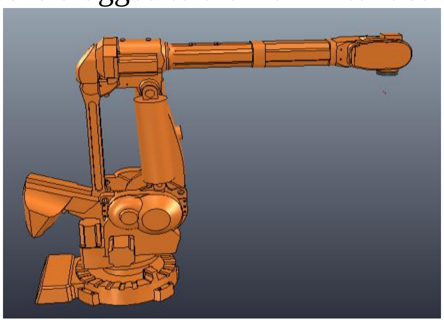
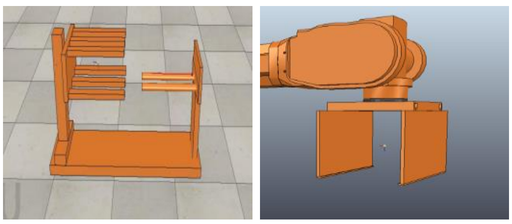


Fig.2 Six degrees of freedom industrial robot model

2.4 Virtual modeling of other palletizing platforms

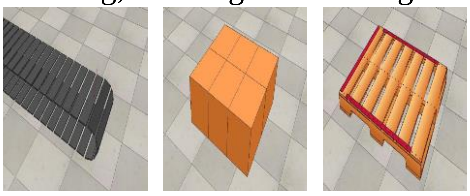
The turnover machine is made up of the fixed support part and the movement support part. The motion bracket part includes two mobile joints and a movable claw hand, and the virtual model is shown in the figure. The sensor is installed on the fixed bracket. When the cigarette bag is placed on the fixed bracket, it will trigger the control motor running of the turnover machine and detect the turning of the cigarette bag on the bracket when it is detected by the sensor on the fixed bracket. The grip usually includes the control system, the driving system, the execution part and the detection device. Virtual modeling is shown in Figure 3.



(a) Flip-flop model (b) gripper model

Fig.3 Flip-flop and gripper model

Conveyor is mainly responsible for the delivery function of cigarette packets, as shown in Figure 4, the buffer zone platform is mainly used for temporary storage of shaped packets, the palletizing system structure diagram, we can see the end of the conveyor placed two caching platforms, trays in the factory Become a necessary transport aircraft, used to make objects assembled into a transport unit, which facilitates the object stacking, handling and stacking.



(a) Conveyor (b) buffer (c) tray models

Fig.4 Conveyor, buffer and tray models

Based on the above model of the palletizing equipment, the entire palletizing system needs to be integrated. According to the programmed program, the actual data of the pouch is input into the automatic matching algorithm. The detailed simulation is shown in Figure 5 Show.

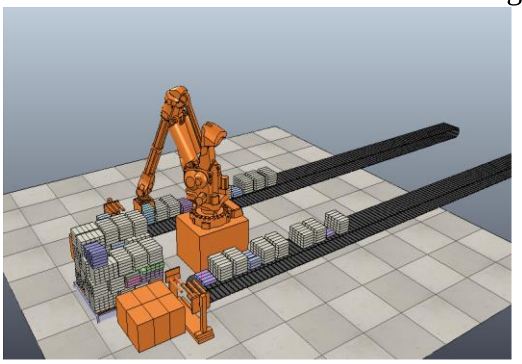


Fig.5 Palletizing renderings

3. Structure and kinematics analysis of the palletizing robot

3.1 Structure of palletizing robot

In this paper, a 6R manipulator is taken as an example to create a connecting rod coordinate system based on the D-H parameter method, as shown in Figure 6. In the graph, the coordinate system $Ox_0y_0z_0$ is the reference coordinate system of the manipulator, the axis z_0 is on the axis of the joint axis 1, the coordinate system $Ox_5y_5z_5$ is the coordinate system of the joint axis 6, the axis z_5 is on the axis of the joint 6, and the origin of the coordinate system is the axis intersection point of the joints 5 and 6.

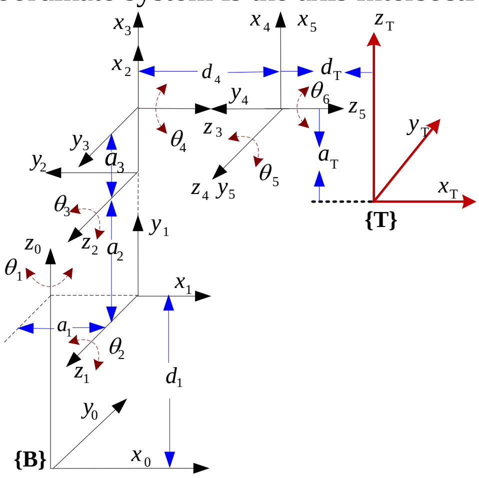


Fig.6 Coordinate diagram of manipulator link

3.2 Joint space trajectory planning

The joint space planning palletizing robot has a function relationship between the joint angle of each joint and the time, the running time between adjacent path points of each joint is equal, it can be independent of each joint trajectory planning, not between mutual influence [8].

In view of the problem that the palletizing trajectory and the polynomial interpolation trajectory are prone to wave, this paper chooses three times spline interpolation method to track [9]. The B spline curve has the characteristics of local control, the control point can be off-line, and the continuity and so on[10]. The three order uniform spline function expression is as follows:

$$\theta_i(u)=\sum_{j=0}^{3}B_{j,3}(u)V_{i+j-1} \tag{1}$$

In the formula, u is a parameter, $0\le u\le 1$； $B_{j,3}(u)$ is a parameter polynomial and satisfies:

$$\begin{cases} B_{0,3}(u)=\frac{1}{6}\left(-u^3+3u^2-3u+1\right) \\ B_{1,3}(u)=\frac{1}{6}\left(3u^2-6u^2+4\right) \\ B_{2,3}(u)=\frac{1}{6}\left(-3u^3+3u^2+3u+1\right) \\ B_{3,3}(u)=\frac{1}{6}u^3 \end{cases} \tag{2}$$

The curve segment $\theta_i(u)$ of the three B spline is as follows:

$$\theta_i(u)=\frac{1}{6}\begin{bmatrix}u^3 & u^2 & u & 1\end{bmatrix}\begin{bmatrix}-1 & 3 & -3 & 1\\ 3 & -6 & 3 & 0\\ -3 & 0 & 3 & 0\\ 1 & 4 & 1 & 0\end{bmatrix}\begin{bmatrix}V_{i-1}\\ V_i\\ V_{i+1}\\ V_{i+2}\end{bmatrix} \tag{6}$$

In the form V_{i-1}, V_i, V_{i+1}, and V_{i+2} are the control points of the B spline curve of the I section. Before evaluating each B spline, we need to find four adjacent control points. We know the path points of a known palletizing robot, and use inverse kinematics to solve the corresponding points of the joint points, then we can get the expression of the three B spline joint motion function.

4. Solving time optimality by genetic algorithm

Genetic algorithm is a random parallel algorithm based on population optimization based on the theory of biological evolution and mutation. It is mainly through selection, crossover, mutation and other genetic operations, so that the population will eventually converge to the global optimal solution [10].

The mathematical model of the key problem of optimal time trajectory optimization based on genetic algorithm is expressed as follows:

$$\begin{cases} T=\min\sum_{i=1}^{m-1}h_i \\ \dot{\theta}_i(u)\le V_i\max \\ \ddot{\theta}_i(u)\le a_i\max \end{cases} \tag{3}$$

In the above, $h_i\,(i=1,2,...,m-1)$ represents the time interval of the B spline in section I, $V_i\max$ and $a_i\max$ represent speed constraints and acceleration constraints, respectively.

Implementation steps:

(1) Code

The time h_i of the motion of the B - spline curve of each segment is encoded into the chromosomes required by the genetic algorithm. Because real number coding has high coding precision, simple and flexible coding and large representation range, real number coding is used in this paper to represent decision variable h_i.

(2) Population initialization

The determination of the initial population is within the range of each segment of h_i, and a certain number of individuals are generated randomly.

(3) Population fitness function f

Fitness value is the basic basis of genetic algorithm is to evaluate the individual standards, this paper uses the penalty function of the outer law, according to the optimization goal to determine the $f = \sum t_i + \varepsilon p$, where p is an added penalty function term and ε is a penalty factor.

(4) options

In this paper, the adaptive genetic mode is used to calculate the evaluation fitness of the population f_{avg}, which is used as the threshold to screen out those individuals whose fitness value is greater than the average fitness value as the offspring individuals.

(5) Adaptive crossover and mutation

Intersection adopts the way of single point crossover to generate new individuals, and the variation operates according to the way of single point mutation. In the early stages of evolution, the crossover probability of the population should be increased to reduce the probability of mutation, so as to avoid the stagnation of the high-quality individuals without undermining the individual structure.In the later stage of evolution, the crossover probability should be reduced to avoid the destruction of the effective model of the best individual, while increasing the mutation probability, enhancing the local search ability and keeping the diversity of the population. According to the fitness value of each generation, the crossover probability P_c and the mutation probability P_m are adaptively adjusted:

$$p_c = \begin{cases} k_1 - \dfrac{(k_1 - k_2)(f' - f_{avg})}{f_{\max} - f_{avg}} & , f' \geq f_{avg} \\ k_1 & , f' < f_{avg} \end{cases} \quad (4)$$

$$p_m = \begin{cases} k_3 - \dfrac{(k_3 - k_4)(f_{avg} - f)}{f_{\max} - f_{avg}} & , f \geq f_{avg} \\ k_3 & , f < f_{avg} \end{cases} \quad (5)$$

In the above formula, f' is a larger fitness value obtained from two individuals with mutual variation, f' is the fitness of the selected individuals participating in the mutation, and the range of k_1, k_2, k_3, k_4 [0, 1].

5. Matlabsimulation and result analysis

In this paper, FANUC ARC 100 i with 6 degrees of freedom is used to study trajectory planning.The kinematic constraints of FANUC ARC 100 i are shown in Table 2, the coordinates of palletizing robots in Cartesian space are shown in Table 3.

Table 2 Robot kinematic constraints

constraint	joint					
	1	2	3	4	5	6
speed $v/(^{\circ}/_{s})$	100	90	95	130	120	105
acceleration $a/(^{\circ}/_{s^2})$	35	30	50	60	45	40

Table 3 Cartesian space robot point path coordinates

End point coordinates	Path point				
	1	2	3	4	5
x / mm	1143.6	1022.3	990.1	876.2	790.3
y / mm	378.2	-16.3	-405.2	-782.7	-1029
z / mm	273.7	-136.8	897.1	893.0	720.9

In the process of genetic optimization, P_c and P_m are adaptively adjusted with the process of evolution. In the process of genetic optimization, the parameters of pops = 100, G = 100, $P_{c\max} = 0.9$, $P_{c\min} = 0.1$, $p_{m\max} = 0.2$, $P_{m\min} = 0.005$. The optimization results are shown in Table 5 below.

Table 5 robot path point joints

time interval	h_1	h_2	h_3	h_4	total time
Initial value	2	2	2	2	10
joint 1	1.032	1.092	0.934	1.025	4.919
joint 2	1.154	0	0.451	0.733	2.973
joint 3	0.326	0	0.058	0.236	0.658
joint 4	0	0	0	0.634	1.359
joint 5	0	0	0	0.725	1.807
joint 6	0	0	0.965	0.542	2.131

It can be seen from the above chart that, in order to meet the constraints of robot speed and acceleration, each joint is optimized for the entire palletization process.

6. Summary

In the design of tobacco palletizing robot scheme, the entire palletizing process was simulated in V-rep for the uncertainty of program setting. On the basis of cubic B-spline, adaptive genetic algorithm Optimization of robot time improves the efficiency of robot trajectory planning. In the follow-up study, more constraints of the manipulator, such as torque, energy and vibration impact, will be considered to further optimize the trajectory of the manipulator.

References

[1] Cai Zixing. Robotics [M]. Beijing: Tsinghua University Press, 2009.

[2] Chen Dan. Optimization of B-spline based on genetic algorithm and its application in robot trajectory planning [D] .Wuhan: Wuhan University of Science and Technology, 2007.

[3] Qin Feng, Xu Xiangrong.Motor locus planning based on spline function method [J] .Journal of Mechanical Science and Technology, 1996,15 (4): 561-565.

[4] Guo T Y, LI F, HUANG K, et al. Application of optimal algorithm on trajectory palnning of mechanical arm based on B-Sline curve[J] . Appied Mechanics and Materials, 2013 , 376 : 253-256.

[5] Li Dongjie, QIU Jiangyan, YOU Bo.Optimization Algorithm of Robot Trajectory Planning [J] .Electric Machines and Control, 2009, 13 (1): 123-127.

[6] Zhou Xiaoyan,Bao Guanjun,IGIA peak,the manipulator trajectory planning based on [J].Mechanical and Electrical Engineering,2009,26(8):1-40.

[7] Peralta E,Fabregas E, Farias G, et al. Development of a Khepera IV Library for the V-REP Simulator[J]. Ifac Papersonline, 2016, 49(6): 81-86.

[8] Zhang Qizhi, Zhou Yali. Concise tutorial on robotics [M]. Xi'an: Xidian University Press, 2013: 68-79.

[9] Ma Dongsheng, Lei Yongjun. Numerical methods [M]. Beijing: Mechanical Industry Press, 2006,157-161.

[10] Ren Zibu, Umbrella governance. Improved adaptive genetic algorithm and its application in system identification [J], Journal of System Simulation, 2006,18 (1).