Parallel Algorithm for Collision Avoidance Motion Planning of Dual Arm Grasping of Humanoid Robot

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Abstract

Aiming at such problems as grasping space limitation, unknown target configuration, DOF redundancy of dual arm and singular configuration for collision avoidance motion planning of simultaneous grasping of high-dimensional space humanoid robot, firstly, forward kinematics for dual arm of humanoid robot and SVD-based inverse kinematics models have been established. Secondly, this paper has put forward a parallel algorithm for dual arm grasping motion planning framework integrating SVD and RRT techniques and DAGRRT collision avoidance motion planning. Finally, the correctness and effectiveness of the algorithm proposed in this paper has been verified via computer 3D visualization simulation.

Keywords: humanoid robot, dual arm grasping, rapidly-exploring random tree (RRT), singular value decomposition (SVD), DAGRRT planner, parallel algorithms.

1 Introduction

The collision avoidance motion planning of complex space object grasped by dual arm of humanoid robot is a typical high-dimensional C-space and nonlinear constrained motion planning issue as well as a challenging frontier research field [1-4]. It is becoming a research focus for scholars at home and abroad [5-10].

At present, the motion planning of high-dimensional space robot mainly includes two kinds of typical random sampling methods: Probabilistic Road Map (PRM) [11-15] and Rapidly-exploring Random Tree (RRT) [16-21].

Kuffner and Wang Wei et al succeeded in applying RRT method in bipedal robot H5 to solve such motion planning problems as walking, gesture conversion, single arm grasping and control [22-24]. As for the structure of joint-type humanoid robot lacking the analytical solution for inverse kinematics, these literatures provide the heuristic information mainly according to the robot's configuration state in the work space end effector, adopt the RRT motion planning method based on random sampling theory and provide new solution ideas for the motion planning of humanoid robot. Bertram et al utilized the distance measurement for the end effector of humanoid robot in work space opposite to the object configuration as the heuristic information for C-space motion planning, and led RRT algorithm to rapid expansion of target configuration [25]. Weghe et al utilized Jacobi matrix transposition method to directly translate the heuristic information in work space into joint space configuration, which has improved the performance of motion planning algorithm of humanoid robot [26]. Berenson et al utilized the projection technology to put forward limited two-way RRT algorithm, move the sampling road points in C-space to the constraint manifold and realize the rapid motion planning of single arm grasping of mechanical arm with 7 DoFs [27-29].

Aiming at the collision avoidance motion planning of dual arm grasping of humanoid robot, this paper firstly studies the modelling methods for forward kinematics and inverse kinematics of dual arm. Secondly, it has put forward the framework model for collision avoidance motion planning of dual arm grasping based on RRT as well as a parallel processing algorithm for DAGRRT collision avoidance motion planning integrating SVD and RRT techniques. Finally, the correctness and effectiveness of the algorithm proposed in this paper has been verified via computer 3D visualization simulation.

2 Model For Dual Arm Kinematics

2.1 FORWARD KINEMATICS

Refer to Fig.1 for schematic diagram for dual arm model of humanoid robot studied in this paper. Left (right) arm has 7 rotational DOFs, and D-H method is adopted to describe each rotational joint parameter (q_i^k , α_i^k , a_i^k , d_i^k). Each coordinate system is recorded as ${}^k\sum_i({}^k x_i, {}^k y_i, {}^k z_i)$, and each joint angle as q_i^k and arm configuration as $\mathbf{q}^k = \left[q_0^k, \quad ..., \quad q_6^k\right]^T$ (k=R, L refer to left/right arm; i=0~6 refer to 7 rotating joints including shoulder 1, shoulder 2, upper arm, elbow, forearm, wrist 1 and wrist 2). If $\sin q_i^k$ and $\cos q_i^k$ are simplified as $s_{q_i^k}$ and $c_{q_i^k}$, the homogeneous transformation matrix ${}^k\mathbf{T}_{i+1}^i(q_i^k)$ between the coordinate systems ${}^k\sum_{i+1}$ and ${}^k\sum_i$ can be expressed as Formula (1):

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$$
{}^{k}\mathbf{T}_{i+1}^{i}(q_i^k)=\begin{bmatrix} c_{q_i^k} & -c_{\alpha_i^k}s_{q_i^k} & s_{\alpha_i^k}s_{q_i^k} & a_i^k c_{q_i^k} \\ s_{q_i^k} & c_{\alpha_i^k}c_{q_i^k} & s_{\alpha_i^k}c_{q_i^k} & a_i^k s_{q_i^k} \\ 0 & s_{\alpha_i^k} & c_{\alpha_i^k} & d_i^k \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}
$$

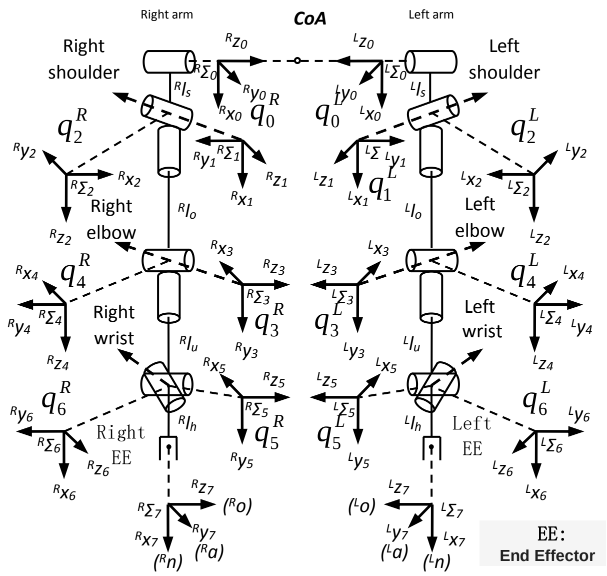

Figure 1 Schematic diagram for dual arm of humanoid robot

When taking dual arm centre (CoA) as an original point of the reference coordinate system $\sum_0$, the matrix form of forward kinematical equation for dual arm can be expressed as Formula (2):

$$
{}^{k}\mathbf{T}_7^0(\mathbf{q}^k)=\prod_{i=0}^{7}{}^{k}\mathbf{T}_{i+1}^{i}(q_i^k)=\mathbf{T}_{tcp}^k , \tag{2}
$$

Wherein, $\mathbf{T}_{tcp}^k=\begin{bmatrix}\mathbf{n}^k & \mathbf{o}^k & \mathbf{a}^k & \mathbf{p}^k \\ 0 & 0 & 0 & 1\end{bmatrix}$ refers to homogeneous matrix of TCP configuration of humanoid robot, n^k, s^k, a^k and p^k refer to normal vector, sliding vector, approach vector and position vector of left (right) arm. Formula (2) can be converted into the classic vector form expressed in Formula (3):

$$
\mathbf{x}^k=\mathbf{f}^k(\mathbf{q}^k) , \tag{3}
$$

Wherein, $\mathbf{q}^k\in R^7$ refers to configuration vector of left (right) arm of humanoid robot, $\mathbf{x}^k[x,y,z,\phi,\theta,\psi]\in R^6$ refers to TCP configuration vector at the end of left (right) arm, including 3D position vector (x, y, z) and 3D Euler angle (ϕ,θ,ψ) configuration vector. The configurations expressed by Euler angle and the configuration described by rotation matrix $\mathbf{R}=[\mathbf{n}\quad \mathbf{o}\quad \mathbf{a}]$ have the following transformational relation. If the Euler angle is known, the rotation matrix $\mathbf{R}$ (4) can be inferred according to $\mathbf{R}=\mathbf{R}_{z,\phi}\mathbf{R}_{y,\theta}\mathbf{R}_{z,\psi}$:

$$
\mathbf{R}=\begin{bmatrix} c_\phi c_\theta c_\psi - s_\phi s_\psi & -c_\phi c_\theta s_\psi - s_\phi c_\psi & c_\phi s_\theta \\ s_\phi c_\theta c_\psi + c_\phi s_\psi & -s_\phi c_\theta s_\psi + c_\phi c_\psi & s_\phi s_\theta \\ -s_\theta c_\phi & s_\theta s_\psi & c_\theta \end{bmatrix} . \tag{4}
$$

If the rotation matrix $\mathbf{R}$ is known, the Euler angle can be calculated according to Formula (5):

$$
\begin{cases} \phi = a\tan 2(a_y, a_x) \\ \theta = a\tan 2(c_\phi a_x + s_\phi a_y, a_z) \\ \psi = a\tan 2(s_\phi n_x + c_\phi n_y, s_\phi s_x + c_\phi s_y) \end{cases} . \tag{5}
$$

Considering that inverse cosine function cannot determine the characteristic of plus-minus sign of the angle, arctan function atan2(y, x) is adopted in this paper to determine the Euler angle within [-π, π].

2.2 FORWARD KINEMATICS

The time t is derived from Formula (3), and then the differential relation (6) between dual arm configuration $\mathbf{q}^k$ and configuration $\mathbf{x}^k$ of dual arm of humanoid robot:

$$
\dot{\mathbf{x}}^k=\mathbf{J}_k(\mathbf{q}^k)\dot{\mathbf{q}}^k , \tag{6}
$$

Where, $\dot{\mathbf{x}}^k$ is the generalized velocity of the end of dual arm of humanoid robot in operating space, $\dot{\mathbf{q}}^k$ is the joint speed, and $\mathbf{J}_k(\mathbf{q}^k)$ is the partial derivative matrix of 6x7. That is, it is Jacobi matrix of dual arm, and the elements in No. i line and No. j row are:

$$
J_{ij}^k(\mathbf{q}^k)=\frac{\partial f_i^k(\mathbf{q}^k)}{\partial q_j^k} \text{ (i=0,…,5 j=0, …,6).} \tag{7}
$$

In the base coordinate system Σ_0, Jacobi matrix $\mathbf{J}_k(\mathbf{q}^k)\in R^{6\times 7}$ of dual arm of humanoid robot can be expressed as Formula (8):

$$
\mathbf{J}_k(\mathbf{q}^k)=[J_1^k(q_0^k)\quad \cdots \quad J_1^k(q_6^k)] , \tag{8}
$$

Wherein, $J_1^k(q_0^k)=\begin{bmatrix} z_i^k\times {}^i p_n^k \\ z_i^k \end{bmatrix}$, z_i^k and ${}^i p_n^k$ are the expressions in the base coordinate system Σ_0, and $\times$ refers to vector product. Use singular value decomposition (SVD), $\mathbf{J}_k(\mathbf{q}^k)$ can be expressed as Formula (9):

$$
\mathbf{J}_k(\mathbf{q}^k)=\mathbf{U}_k\mathbf{D}_k\mathbf{V}_k^T , \tag{9}
$$

Wherein, $\mathbf{U}_k\in R^{6\times 7}$ and $\mathbf{V}_k\in R^{7\times 7}$ are orthogonal matrixes, $\mathbf{D}_k\in R^{6\times 7}$. Thus, the generalized inverse matrix $\mathbf{J}_k^+(\mathbf{q}^k)$ can be written as the vector form in Formula (10):

$$
\mathbf{J}_k^+(\mathbf{q}^k)=\sum_{i=1}^{r}\sigma_i^{-1}v_i u_i^T , \tag{10}
$$

Wherein, $\sigma_i=d_{i,i}$ is $\mathbf{J}_k(\mathbf{q}^k)$ eigenvalue of $\mathbf{J}_k(\mathbf{q}^k)$, r is the sequence of $\mathbf{J}_k(\mathbf{q}^k)$. u_i and v_i refer to No. I row of $\mathbf{U}_k$ and $\mathbf{V}_k$ respectively.

Therefore, according to Formula (6), the differential form for inverse kinematics of dual arm of humanoid robot based on SVD can be written as Formula (11):

$$\dot{\mathbf{q}}^k = \mathbf{J}_k^+(\mathbf{q}^k)\dot{\mathbf{x}}^k . \quad (11)$$

To facilitate the numerical calculation, the increment equation for inverse in Formula (11) can be expressed as Formula (12):

$$\Delta\mathbf{q}^k = \mathbf{J}_k^+(\mathbf{q}^k)\Delta\mathbf{x}^k . \quad (12)$$

3 DAGRRT algorithm

Refer to Fig.2 for simultaneous grasping of 3D space object by the dual arm of humanoid robot integrating RRT and SVD techniques and the framework of collision avoidance motion planner DAGRRT (Dual-Arm Grasping RRT). Refer to Algorithm 1 for its core pseudo-code realization. DAPGT: DArms Parallel Grasp Trajectory; SAGT:Single Arm Grasp Trajectory.

Algorithm 1: DAGRRT($\mathbf{q}_s^L$, $\mathbf{q}_s^R$, $\mathbf{x}_{obj}$) {

RRT^L = GRRT($\mathbf{q}_s^L$, $\mathbf{x}_{obj}$);// construct grasping object of left arm

RRT^R = GRRT($\mathbf{q}_s^R$, $\mathbf{x}_{obj}$);//construct grasping object of right arm

RRT^L .start(); RRT^R .start();//start planning process of left and right arms

do {

#pragma omp parallel // OpenMP parallelization of left arm algorithm.

$s^L = RRT^L$ .getNewPath();//process the outcome of left arm planning

if(s^L) {//if the path is non-void

S^L .add(s^L); add it to the outcome set of left arm planning

foreach($s^R \in S^R$) {//traverse the outcome set of right arm planning

//if meeting grasping quality criteria and collision avoidance requirements

if(GraspScore(s^L , s^R)> $gs_{\min}$)&&

!Collision(s^L , s^R)) { StopLoop=true;

}}

#pragma omp parallel // OpenMP parallelization of right arm algorithm.

$s^R = RRT^R$ .getNewPath();//process the outcome of right arm planning

if(s^R) {//if the path is non-void

S^R .add(s^R) add it to the outcome set of left arm planning

foreach($s^L \in S^L$) {// traverse the outcome set of left arm planning

if(GraspScore(s^L , s^R)> $gs_{\min}$)&&

!Collision(s^L , s^R)) { StopLoop=true;

}}

}while(!StopLoop);

#pragma omp critical //the main thread waits for the completion of other paralleled tasks

RRT^L .stop(); RRT^R .stop ();//stop the planning process of left and right arms

return CreatePath(s^L , s^R) ;}

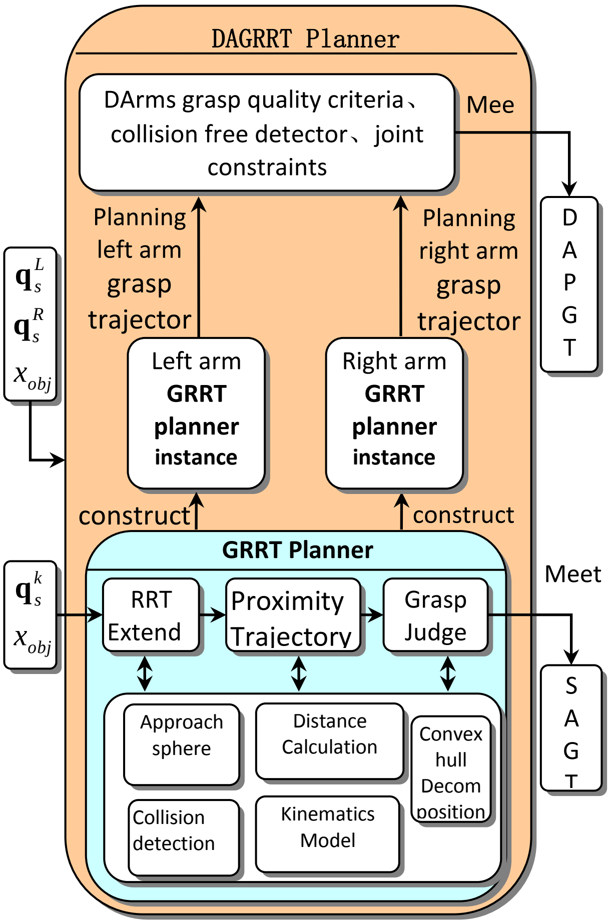

FIGURE 2 DAGRRT planner framework

Explanation for Algorithm 1: To realize the parallel planning of dual arm grasping, left (right) arm grasping planner GRRT(q_s^k , $\mathbf{x}_{obj}$) adopts independent thread realization (k=R, L refer to left and right arms), and the superscript L($) is marked as relevant planning parameters of left (right) arms. Multi-core technology based on OpenMP is used to realize the parallelization processing for the algorithm so as to accelerate the planning. Parameter $gs_{\min}$ is the minimum evaluation index to judge the effectiveness of object grasped by dual arm. C_{grasp}^L and C_{grasp}^R refer to the contact point sets for left and right hands. According to the hand grasping force closing principle obtained from the analysis of grasping wrench space (GWS), the union set $C_{grasp} = C_{grasp}^L \cup C_{grasp}^R$ can be used to adjust contact force, construct the convex hull, which is similar to single hand and then realize the pseudo-code of GraspScore (s^L , s^R), as shown in Algorithm 2 ($n_{contact}^L$ and $n_{contact}^R$ refer to the minimum finger quantity for left and right hands to contact with the objects.). Collision (s^L , s^R) is realized by adopting HBV (Hierarchical Bounding Volume) algorithm for directions, and its basic idea is as follows: A big solid bounding volume is used to substitute the geometrical model of complex objects. By intersection test among bounding volumes, the non-intersection basic geometrical element pairs can be quickly eliminated so as to reduce the workload of intersection test. To realize the collision detection precision, the hierarchical method should be firstly adopted to establish HBV and approach to the complex geometrical model until all characteristics of the model can be completely described, and then separating axis theory can be used to conduct dual traversal test among bounding box trees so as to judge whether there is any collision [30-34].

Algorithm 2: GraspScore(s, s^R){
C^L_{grasp} = GetContactPoints(s^L);//calculate the contact point set for left hand
C^R_{grasp} = GetContactPoints(s^R);//calculate the contact point set for left hand
if($\left|C^L_{grasp}\right| < n^L_{contact}$ || $\left|C^R_{grasp}\right| < n^R_{contact}$) return 0;
$C_{grasp} = C^L_{grasp} \cup C^R_{grasp}$;
return GraspQualityMeasure(C_{grasp});}

Refer to Algorithm for pseudo-code realization of left (right) arm grasping planner GRRT algorithm.

Algorithm 3: GRRT($\mathbf{q}^k_s$, $\mathbf{x}_{obj}$) {
RRT^k .initConfig(q^k_s);//set initial configuration of RRT tree
StopLoop=false;// set stop loop mark
do {
f_r = rand()* (1.0/(0x7fff));// generate random sampling probability between (0, 1)
if (f_r <= f ConnectJacobian){// execute routine extend/connect
ExtGraspStatus= RRT^k .ApproachToTarget ($\mathbf{x}_{obj}$);
switch (ExtGraspStatus) {
case FatalError: StopSearch=true; break;//fatal error
case TargetReached://reach target grasping configuration
if (Grasps.size()<=0) StopSearch=true;//stop searching
else { FoundSolution=true;//find search solution
graspInfo = Grasps[Grasps.size()-1];
$\mathbf{q}^k_g$ =getTargetConfig(graspInfo.nRrtNodeId);}
break;}//obtain the target configuration
}else {//Expand to C-space random configuration
RRT^k .getRandConfig ($\mathbf{q}^k_r$);//obtain C-space random configuration
$\mathbf{q}^k_n$ = RRT^k .NNConfig($\mathbf{q}^k_r$);//search RRT nearest configuration
ExtStatus= RRT^k .Connect ($\mathbf{q}^k_n$, $\mathbf{q}^k_r$, $\mathbf{q}^k_{new}$);
RRT^k .addConfig($\mathbf{q}^k_{new}$);//add new configuration to RRT tree
if (ExtendStatus==ERROR) StopSearch=true;
}
Cycles++;//add 1 to search times
if (StopSearch|| FoundSolution||(Cycles>MaxCycles))
StopLoop=true;//set stop loop mark
} while(!StopLoop);
getNewPath ($\mathbf{q}^k_s$, $\mathbf{q}^k_g$) ;}

Explanation for Algorithm 3: Set f ConnectJacobian as 0.3, the maximum cycle search times are MaxCycles＝40,000. getRandConfig ($\mathbf{q}^k_r$) are evenly distributed in left (right) C-space. After random sampling, the random configuration $\mathbf{q}^k_r = \mathbf{q}^k_{\min}$ + rand() * (1/ 0x7fff)*($\mathbf{q}^k_{\max}$ - $\mathbf{q}^k_{\min}$) can be obtained. NNConfig ($\mathbf{q}^k_r$) seeks the configuration $\mathbf{q}^k_n$, which is nearest to $\mathbf{q}^k_r$ in left (right) arm rapidly-exploring random tree RRT^k . That is, $\min\left\|\mathbf{q}^k_n - \mathbf{q}^k_r\right\|^2 = \min\sum_{i=0}^{6}(q^k_{n,i} - q^k_{r,i})^2$. Connect ($\mathbf{q}^k_n$, $\mathbf{q}^k_r$, $\mathbf{q}^k_{new}$) realizes the expansion for left (right) arms of humanoid robot from the nearest configuration $\mathbf{q}^k_n$ to the random configuration $\mathbf{q}^k_r$ until the obstacle is met. A new configuration $\mathbf{q}^k_{new}$ is obtained and added to RRT^k . Its schematic diagram for operating principle is shown in Figure 3.

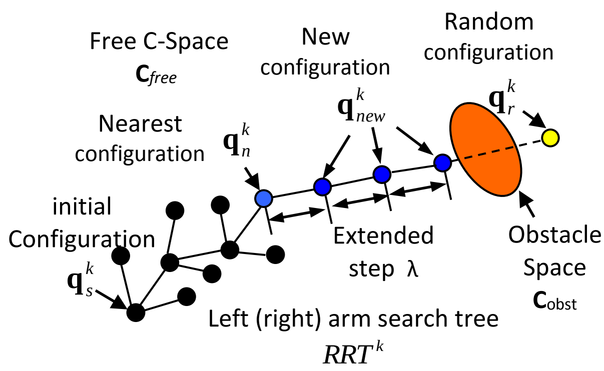

FIGURE 3 Operating priniple of Connect ($\mathbf{q}^k_n$, $\mathbf{q}^k_r$, $\mathbf{q}^k_{new}$)

ApproachToTarget ($\mathbf{x}_{obj}$) is to adopt the core algorithm, in which SVD generalized inverse kinematics expands to the target configuration. Its pseudo-code realization is shown in Algorithm 4.

Algorithm 4: ApproachToTarget ($\mathbf{x}_{obj}$){
calculateGlobalGraspPose(grasp); //calculate global grasping object
$\mathbf{x}^k_{target}$ = ComputeTargetPose(grasp, $\mathbf{x}_{obj}$);//target configuration
$\mathbf{q}^k_{near}$ = RRT^k .GetNearestNeighbor($\mathbf{x}^k_{target}$);
do {
$\mathbf{x}^k_{near}$ = FK^k ($\mathbf{q}^k_{near}$);//forward kinematics of left (right) arms as per Formula (3)
$\Delta\mathbf{x}^k = \mathbf{x}^k_{target} - \mathbf{x}^k_{near}$;//calculate Cartesian space configuration difference

07 $\Delta\mathbf{x}^k_{step}$ =LimitStepSize ($\Delta\mathbf{x}^k$);// calculate configuration increment
08 $\Delta\mathbf{q}^k = \mathbf{J}^+_k(\mathbf{q}^k_{near}) * \Delta\mathbf{x}^k$; //obtain configuration increment as per Formula (12)
09 $\mathbf{q}^k_{near} \mathrel{+}= \Delta\mathbf{q}^k$;// calculate the new configuration after artificial arm moves the little configuration
10 if (Collision ($\mathbf{q}^k_{near}$) || !InJointLimits($\mathbf{q}^k_{near}$))
11 return FatalError;
12 RRT^k .AddConfig ($\mathbf{q}^k_{near}$);
13 }while ($\left\|\Delta\mathbf{x}^k\right\| \geq \left\|\Delta\mathbf{x}^k_{Threshold}\right\|$) ;
14 return TargetReached; }

Algorithm 4: No.05 code is realized according to the forward kinematics of left (right) arms of humanoid robot. No. 08 line code calculates the configuration increment and is realized according to increment equation (12) for inverse kinematics of left (right) arms based on SVD.

4 Computer 3d Simulation

Taking parallel grasping complex object by dual arm of humanoid robot in a multiple-obstacle environment, this paper has conducted a lot of computer 3D visualization simulation experimental verifications and researches on the proposed DAGRRT collision avoidance motion planning algorithm. Refer to Table 1 for D-H ($\theta_i s$, α_i , a_i , d_i) parameters for dual arm of humanoid robot. Left (right) arm has 7 rotating joints, the configuration space is $\mathbf{q}^k = \left[q^k_0, \quad ..., \quad q^k_6\right]^T$ (k=R, L refer to left arm and right arm), each joint angle is randomly sampled within the scope of joint constraint. Open Inventor is adopted to construct 3D simulation scenarios including artificial dual arm, object and obstacle, and hierarchical bounding volumes algorithm for directions proposed by Gottschalk et al is applied to realize self-collision detection of dual arm of humanoid robot and scenario collision detection between humanoid robot and object or obstacle. Refer to Figure 4 for 3D display of planning outcome obtained from dual arm grasping object by DAGRRT algorithm, and 6 rectangle obstacles are randomly placed in the work space of humanoid robot. Subgraph (1) is initial configuration for dual arm, the initial configuration of left arm end effector is ($x, y, z, \phi, \theta, \psi$) = (-729.387, 150.811, 1296.943, 1.669, 0.992,-2.542), and the initial configuration of right arm end effector is (390.833, 138.736, 1320. 031,-1.214, 1.048, 0.587). Subgraphs (2) and (3) are the middle grasping configurations of dual arm. Subgraph (4) is the grasping target configuration obtained from planning. The target configuration of left arm end effector is -204.765, 516.069, 1302.585, -0.150, -0.952, -2.499), and the target configuration of right arm end effector is (207.720, 416. 536, 1146. 943,-1.874, 0.587, 0.317). Fig.5 is a 3D dynamic process of DAGRRT planning observed from different perspectives. Figure 6 is 3D effect for simultaneously displaying RRT path and grasping set. Figure 7 is tracks after smoothness optimizing process of dual arm configuration obtained from DAGRRT algorithm. It can be seen from simulation outcome that the algorithm proposed in this paper can realize in parallel the operation task of collision avoidance motion planning of dual arm grasping object of humanoid robot accurately, effectively and efficiently in a complex obstacle environment.

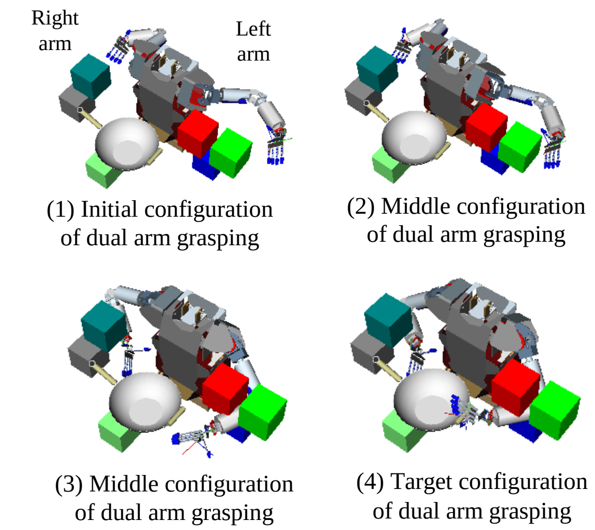

FIGURE 4 3D display of DAGRRT planning results

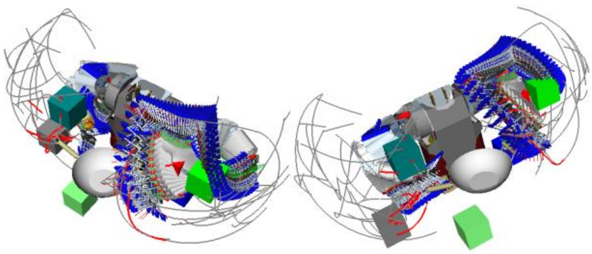

FIGURE 5 3D dynamic process of DAGRRT planning

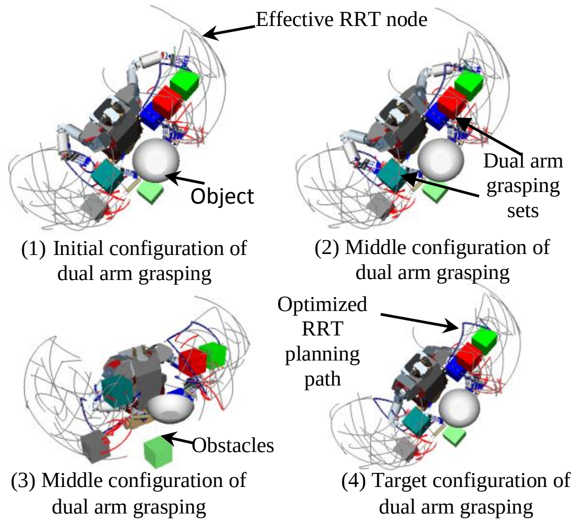

FIGURE 6 3D effect for simultaneously displaying RRT path and grasping set

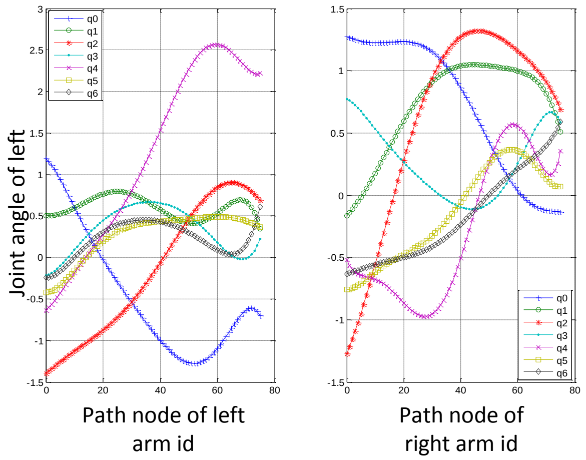

Figure 7 Tracks after smoothness optimizing process of dual arm configuration

TABLE 1 D-H parameters for dual arm of humanoid robot

Joint Varia bles	Theta (rad)	Alpha (rad)	a (mm)	d (mm)	joint constraint (rad)
q_0^L	π/2	π/2	0	0	[-π/2, π/2]
q_1^L	π/2	π/2	0	0	[-π/2, π/2]
q_2^L	-π/2	π/2	20	-310	[-23π/18,π/2]
q_3^L	0	-π/2	0	-7.5	[-23π/18,π/2]
q_4^L	π/2	-π/2	0	-240	[-π, π]
q_5^L	-π/2	-π/2	0	0	[-π/2, π/2]
q_6^L	-π/2	π/2	0	0	[-π/2, π/2]
q_0^R	0	-π/2	0	0	[-π/2, π/2]
q_1^R	-π/2	-π/2	0	0	[-π/2, π/2]
q_2^R	π/2	π/2	20	-310	[-23π/18,π/2]
q_3^R	0	-π/2	0	7.5	[-23π/18,π/2]
q_4^R	0	π/2	0	-240	[-π, π]
q_5^R	π/2	-π/2	0	0	[-π/2, π/2]
q_6^R	0	π/2	0	0	[-π/2, π/2]

5 Conclusion

Grasping operation of dual arm collision avoidance of humanoid robot is a critical technique involved in the motion planning research of humanoid robot. Aiming at such problems as grasping space limitation, redundancy constraint and unknown target configuration, this paper has put forward a dual arm grasping motion planning DAGRRT framework integrating SVD and RRT techniques and the realization of parallel processing algorithm. On the one hand, it makes full use of rapidly-exploring random tree (RRT) to seek completeness characteristic of the path; on the other hand, it uses singular value decomposition (SVD) to seek configuration singularity, meet inverse kinematics of dual arm in joint constraint, lead the dual arm of humanoid robot to parallel and expand from initial configuration to target object, find a collision avoidance path and complete the object grasping by dual arm. This method is of universal significance to simultaneous grasping by dual arm or control operation of humanoid robot for dynamic target or unknown target position in a complex environment.

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