

WHAT IS CLAIMED IS:

1. A system of controlling obstacle avoidance of a robot, comprising:

a determination module, which is used for acquiring current positioning data of the robot in real time or regularly, and determining whether an obstacle, which is spaced from a current position at a distance shorter than a preset distance, exists in a path from the current position to a target position or not according to the current positioning data and position data of all obstacles in a predetermined moving region;

a calculation module, which is used for calculating the shortest distance between the robot and the obstacle according to the acquired positioning data, a predetermined 3D model of the robot and a predetermined 3D model of the obstacle, if the obstacle, which is spaced from the current position at the distance shorter than the preset distance, exists;

a control module, which is used for calculating a due movement direction of the current robot according to the acquired positioning data, the calculated shortest distance and the 3D model of the obstacle, and controlling a movement posture of the robot according to the calculated movement direction to avoid the potential obstacle;

wherein the calculation module is further configured to:

preprocess the predetermined 3D model of the robot and the predetermined 3D model of the obstacle, and for each joint of the robot, determine a minimum convex polyhedron surrounding each joint by using a predetermined algorithm to convert a robot non-convex model into a convex model; carries out a sector equal division on the predetermined 3D model of the obstacle, and then carries out convex decomposition on single sectors subjected to the sector equal division; and

calculate the shortest distance between the robot and the obstacle by using a predetermined distance calculation rule according to the current positioning data, the preprocessed 3D model data of the robot and the preprocessed 3D model data of the obstacle.

2. The system of controlling obstacle avoidance of the robot of claim 1, wherein the calculation module is configured to:

build a spherical bounding box of the 3D model of the obstacle to be subjected to sector equal division, and find out the sphere center of the spherical bounding box;

set an initial sector equal division plane passing through the sphere center, and rotates the plane for multiple times around the sphere center according to a preset rotating angle to equally divide the spherical bounding box into a plurality of sector portions, wherein the plurality of sector portions of the spherical bounding box serve as a plurality of model portions of the 3D model of the obstacle.

3. The system of controlling obstacle avoidance of the robot of claim 1, wherein the predetermined distance calculation rule comprises:

selecting all the model portions obtained by the sector equal division of the 3D model of the obstacle according to the current positioning data of the robot and a predetermined selection algorithm to select a model portion to be subjected to distance calculation;

calculating the shortest distance between the robot and the selected model portion using a predetermined distance calculation algorithm according to the current positioning data and the selected model portion, wherein the shortest distance is the shortest distance between the robot and the obstacle;

and wherein the predetermined selection algorithm comprises:

by respectively taking the plurality of model portions of the 3D model of the obstacle as n nodes of the obstacle, and building a hash table, in which key-values respectively correspond to the deflection angles of the initial sector equal division plane to carry out model node management;

numbering all the model portions, and according to the numbers, building a deflection angle mapping relation of a sector model portion No. i , wherein a hash function representing the deflection angle mapping relation is defined as:

$$Hash(i) = i * \left(\frac{360^\circ}{n} \right)$$

where $Hash(i)$ represents a deflection angle between the sector model portion No. i and the positive x axis of an obstacle coordinate system, wherein n is a total number of model positions;

building a kinematical equation of the robot, and calculating positions and postures of all the joints of the robot according to the built kinematical equation, wherein the kinematical equation is as follows:

$$T_i = A_0 A_1 A_2 \cdots A_{i-1} A_i$$

where A_k ($k=1, 2, \dots, i$) is a homogeneous transformation matrix among joint coordinate systems of the robot, A_0 represents the current position matrix of the robot, and T_i represents the position and the posture of the i th joint relative to a robot coordinate system;

calculating coordinates Q_i (x, y, z) of all the joints under the robot coordinate system during moving of the robot according to T_i , and calculating a transformation matrix T_r for transforming the robot coordinate system to the obstacle coordinate

system, wherein coordinates $Q_i(x_i, y_i, z_i)$ of each robot joint under the obstacle coordinate system is as follows:

$$Q_i(x_i, y_i, z_i) = T_r Q_i(x, y, z)$$

the deflection angle α of each joint under the obstacle coordinate system is obtained through the following formula:

$$\tan(\alpha) = \frac{y_i}{x_i},$$

and corresponding numbered model portions are calculated according to the deflection angle α and the hash function $Hash(i)$, and the model portions to be subjected to the distance calculation are selected on the basis of the correspondingly numbered model portions.

4. The system of controlling obstacle avoidance of the robot of claim 1, wherein the control module is configured to:

project the 3D model of the robot and the obstacle into the same coordinate system plane;

calculate an area of an effective blocking region of a projection of the 3D model of the obstacle relative to the current position of the robot and the target position according to a predetermined projection analysis rule and coordinates of all points on the outer contour of a projection region obtained by projecting the 3D model of the obstacle to the coordinate system plane;

determine a first preset type of obstacle avoidance parameter according to the shortest distance and the area of the effective blocking region, determining a second preset type of obstacle avoidance parameter according to a distance between the target position and the current position of the robot, and determine the current due

movement direction of the robot according to the first preset type of obstacle avoidance parameter and the second preset type of obstacle avoidance parameter.

5. The system of controlling obstacle avoidance of the robot of claim 4, wherein the predetermined projection analysis rule is as follows:

setting a position point P_1 on the coordinate system plane to represent the current position of the robot, wherein a position point P_2 is the target position, a projection region P3 is a projection of the 3D model of the obstacle in the coordinate system plane, and P_1 and P_2 are connected in the coordinate system plane to obtain a straight line J;

if the straight line J and the projection region P3 do not have an intersection or only have one intersection, determining that no effective blocking region exists;

if the straight line J and the projection region P3 have more than one intersection, partitioning the projection into two portions by the straight line J; finding any point P_s in the projection region P3, making a perpendicular line of the straight line J in a manner of passing through P_s , and setting an intersection between the perpendicular line and the straight line J as P_J , thus obtaining a vector $\overrightarrow{P_J P_s}$; calculating an included angle θ between the vector $\vec{d}$ of the shortest distance and the vector $\overrightarrow{P_J P_s}$; if the included angle θ is an acute angle, determining that the region where the point P_s is located is the effective blocking region, or if the included angle θ is not an acute angle, determining that the region where the point P_s is located is not the effective blocking region.

6. The system of controlling obstacle avoidance of the robot of claim 4, wherein the first preset type of obstacle avoidance parameter is a virtual repulsive force, and

the second preset type of obstacle avoidance parameter is a virtual attractive force;
and the control module is further configured to:

calculate the virtual repulsive force acting on the robot by using a first calculation rule according to the calculated shortest distance and the area of the effective blocking region;

calculate the virtual attractive force acting on the robot by using a second calculation rule according to the distance between the current position and the target point position;

calculate a resultant force direction of the virtual attractive force and the virtual repulsive force, which serves as the current due movement direction of the robot.

7. The system of controlling obstacle avoidance of the robot of claim 6, wherein the first calculation rule is as follows:

setting the vector of the shortest distance between the robot and the obstacle as $\vec{d}$, setting the area of the effective blocking region as S , and setting the virtual repulsive force from the obstacle to the robot as $\vec{F}_r$, wherein the calculation formula is as follows:

$$F_r = f(d, s) = \begin{cases} 0 & d > d_0 \\ \frac{k_r}{d} + b_r & d \leq d_0, s \leq s_0 \\ \frac{k_r}{d} * \frac{s}{s_0} + b_r & d \leq d_0, s > s_0 \end{cases}$$

where $\vec{d}$ is the vector of the shortest distance between the robot and the obstacle,

S is the area of the effective blocking region, $\vec{F}_r$ is the virtual repulsive force from the

obstacle to the robot, k_r and b_r represent preset virtual repulsive force coefficients, s_0 represents a preset area threshold value of the effective blocking region, and d_0 represents a preset distance threshold value; and the direction of $\vec{F}_r$ is the same as that of the shortest distance.

8. The system of controlling obstacle avoidance of the robot of claim 6, wherein the second calculation rule is as follows:

$$F_t = k_t * d_t$$

where $\vec{F}_t$ is the virtual attractive force from the target position to the robot, k_t represents a preset attractive force coefficient, d_t represents a distance between the target position and the current position of the robot, and the direction of the $\vec{F}_t$ is towards the target position.

9. A method of obstacle avoidance of a robot, comprising:

A1, acquiring a current positioning data of the robot in real time or regularly, and determining whether an obstacle, which is spaced from a current position at a distance shorter than a preset distance, exists in a path from the current position to a target position or not according to the current positioning data and position data of all obstacles in a predetermined moving region;

A2, if the obstacle, which is spaced from the current position at the distance shorter than the preset distance, calculating the shortest distance between the robot and the obstacle according to the acquired positioning data, a predetermined 3D model of the robot and a predetermined 3D model of the obstacle;

A3, calculating a due movement direction of the current robot according to the acquired positioning data, the calculated shortest distance and the 3D model of the obstacle, and controlling a movement posture of the robot according to the calculated movement direction to avoid the potential obstacles;

wherein the step A2 comprises:

preprocessing the predetermined 3D model of the robot and the predetermined 3D model of the obstacle, and for each joint of the robot, determining a minimum convex polyhedron surrounding each joint by directly using a predetermined algorithm to convert the robot non-convex model into a convex model;

carrying out a sector equal division on the predetermined 3D model of the obstacle, and then carrying out a convex decomposition on single sectors subjected to the sector equal division;

calculating the shortest distance between the robot and the obstacle by using a predetermined distance calculation rule according to the current positioning data, the preprocessed 3D model data of the robot and the preprocessed 3D model data or the obstacle.

10. The method of obstacle avoidance of the robot of claim 9, wherein the step A2 further comprises:

building a spherical bounding box of the 3D model of the obstacle to be subjected to the sector equal division, and finding out the sphere center of the spherical bounding box;

setting an initial sector equal division plane passing through the sphere center, and rotating the plane for multiple times around the sphere center according to a preset rotating angle to equally divide the spherical bounding box into a plurality of

sector portions, wherein the plurality of sector portions of the spherical bounding box serve as a plurality of model portions of the 3D model of the obstacle.

11. The method of obstacle avoidance of the robot of claim 9, wherein the predetermined distance calculation rule comprises:

selecting all the model portions obtained by the sector equal division of the 3D model of the obstacle according to the current positioning data of the robot and a predetermined selection algorithm to select a model portion to be subjected to distance calculation;

calculating the shortest distance between the robot and the selected model portion by using a predetermined distance calculation algorithm according to the current positioning data and the selected model portion, wherein the shortest distance is the shortest distance between the robot and the obstacle;

and wherein the predetermined selection algorithm comprises:

by respectively taking the plurality of model portions obtained by the sector equal division of the 3D model of the obstacle as a plurality of nodes of the obstacle, and building a hash table, in which key-values respectively correspond to the deflection angles of the initial sector equal division plane to carry out model node management;

numbering all the model portions, and according to the numbers, building a deflection angle mapping relation of a sector model portion No. i, wherein a hash function representing the deflection angle mapping relation is defined as:

$$Hash(i) = i * \left(\frac{360^\circ}{n} \right)$$

where $\text{Hash}(i)$ represents a deflection angle between the sector model portion No. i and the positive x axis of an obstacle coordinate system, wherein n is a total number of model positions;

building a kinematical equation of the robot, and calculating positions and postures of all the joints of the robot according to the built kinematical equation, wherein the kinematical equation is as follows:

$$T_i = A_0 A_1 A_2 \cdots A_{i-1} A_i$$

where A_k ($k=1, 2, \dots, i$) is a homogeneous transformation matrix among joint coordinate systems of the robot, A_0 represents the current position matrix of the robot, and T_i represents the position and the posture of the i th joint relative to a robot coordinate system;

calculating coordinates $Q_i(x, y, z)$ of all the joints under the robot coordinate system during moving of the robot according to T_i , and calculating a transformation matrix T_r for transforming the robot coordinate system to the obstacle coordinate system, wherein coordinates $Q_i(x_t, y_t, z_t)$ of each robot joint under the obstacle coordinate system is as follows:

$$Q_i(x_t, y_t, z_t) = T_r Q_i(x, y, z)$$

the deflection angle α of each joint under the obstacle coordinate system is obtained through the following formula:

$$\tan(\alpha) = \frac{y_t}{x_t},$$

and corresponding numbered model portions are calculated according to the deflection angle α and the hash function $\text{Hash}(i)$, and the model portions to be

subjected to the distance calculation are selected on the basis of the correspondingly numbered model portions.

12. The method of obstacle avoidance of the robot of claim 9, wherein the step A3 comprises:

projecting the 3D model of the robot and the obstacle into a same coordinate system plane;

calculating an area of an effective blocking region of a projection of the 3D model of the obstacle relative to the current position of the robot and the target position according to a predetermined projection analysis rule and coordinates of all points on the outer contour of a projection region obtained by projecting the 3D model of the obstacle to the coordinate system plane;

determining a first preset type of obstacle avoidance parameter according to the calculated shortest distance and an area of the effective blocking region, determining a second preset type of obstacle avoidance parameter according to a distance between the target position and the current position of the robot, and determining the current due movement direction of the robot according to the first preset type of obstacle avoidance parameter and the second preset type of obstacle avoidance parameter.

13. The method of obstacle avoidance of the robot of claim 12, wherein the predetermined projection analysis rule is as follows:

setting a position point P_1 on the coordinate system plane to represent the current position of the robot, wherein a position point P_2 is the target position, a projection region P3 is a projection of the 3D model of the obstacle in the coordinate system plane, and P_1 and P_2 are connected in the coordinate system plane to obtain a straight line J;

if the straight line J and the projection region P3 do not have an intersection or only have one intersection, determining that no effective blocking region exists;

if the straight line J and the projection region P3 have more than one intersection, partitioning the projection into two portions by the straight line J; finding any point P_s in the projection region P3, making a perpendicular line of the straight line J in a manner of passing through P_s , and setting an intersection between the perpendicular line and the straight line J as P_J , thus obtaining a vector $\overrightarrow{P_J P_s}$; calculating an included angle θ between the vector $\vec{d}$ of the shortest distance and the vector $\overrightarrow{P_J P_s}$; if the included angle θ is an acute angle, determining that the region where the point P_s is located is the effective blocking region, or if the included angle θ is not an acute angle, determining that the region where the point P_s is located is not the effective blocking region.

14. The method of obstacle avoidance of the robot of claim 12, wherein the first preset type of obstacle avoidance parameter is a virtual repulsive force, and the second preset type of obstacle avoidance parameter is a virtual attractive force; and the step A3 further comprises:

calculating the virtual repulsive force acting on the robot by using a first calculation rule according to the calculated shortest distance and the area of the effective blocking region;

calculating the virtual attractive force acting on the robot by using a second calculation rule according to the distance between the current position and the target point position;

calculating a resultant force direction of the virtual attractive force and the virtual repulsive force, which serves as the current due movement direction of the robot.

15. The method of obstacle avoidance of the robot of claim 14, wherein the first calculation rule is as follows:

setting the vector of the shortest distance between the robot and the obstacle as $\vec{d}$, setting the area of the effective blocking region as S , and setting the virtual repulsive force from the obstacle to the robot as $\vec{F}_r$, wherein the calculation formula is as follows:

$$F_r = f(d, s) = \begin{cases} 0 & d > d_0 \\ \frac{k_r}{d} + b_r & d \leq d_0, s \leq s_0 \\ \frac{k_r}{d} * \frac{s}{s_0} + b_r & d \leq d_0, s > s_0 \end{cases}$$

where $\vec{d}$ is the vector of the shortest distance between the robot and the obstacle, S is the area of the effective blocking region, $\vec{F}_r$ is the virtual repulsive force from the obstacle to the robot, k_r and b_r represents preset virtual repulsive force coefficients, s_0 represents a preset area threshold value of the effective blocking region, and d_0 represents a preset distance threshold value; and the direction of $\vec{F}_r$ is the same as that of the shortest distance.

16. The method of obstacle avoidance of the robot of claim 14, wherein the second calculation rule is as follows:

$$F_t = k_t * d_t$$

where $\vec{F}_t$ is the virtual attractive force from the target position to the robot, k_t represents a preset attractive force coefficient, d_t represents a distance between the target position and the current position of the robot, and the direction of $\vec{F}_t$ is towards the target position.

17. A robot, comprising a processor and a memory, wherein the memory stores a system of controlling obstacle avoidance of the robot, and the system of controlling obstacle avoidance of the robot may be executed by the processor to implement any step in the method of obstacle avoidance of the robot of claims 9 to 16.

18. A computer readable storage medium, which stores a system of controlling obstacle avoidance of the robot, wherein the system of controlling obstacle avoidance of the robot may be executed by the processor to implement any step in the method of obstacle avoidance of the robot of claims 9 to 16.