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Research on the motion control of omni-directional mobile manipulators

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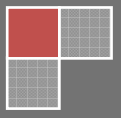
ABSTRACT

To solve the problem of the low work efficiency led by the fact that the manipulator can not be controlled flexibly, the present paper puts forward a project of accurately positioning information and the timely movement controlling of the manipulator. In this set of controlling project, in order to improve the controlling precision and timing of manipulator, the CAN bus technology is used, and two operation modes of the manipulator, namely the fixed-point steering and straight running, are studied. By using ultrasonic precise positioning technology, it is ensured that the measurement of free activities of the manipulator can be controlled, thus ensuring the work efficiency of manipulator. In order to verify the correctness of the proposed scheme, and the rationality of the adopted technology, the article did three experiments on the motion of manipulators. One of them is used to prove that control scheme is correct, and the other two are used to verify that controlling of omni-directional manipulator motion is high precise and can position accurately.

KEYWORDS

Accurate positioning; Omni-directional mobile manipulators; Straight-line running and the fixed-point steering; Flexible positioning and orientating.



INTRODUCTION

An omni-directional mobile manipulator can steer free and moveflexibly on the ground, as well as keep the car's overall position unchanged. Manipulators can directly stretch and move freely in the space where can hold the manipulator, accomplishing the operation task on schedule. Unique function of flexible movement of the omni-directional mobile manipulatorand advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. So the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. And the key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. The situation of robot's movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology. Due to the deviation and delay among the three stages as information collection, transmission, and processing, this solution can not be absolutely real-time and accurate in positioning. In this article, using the ultrasonic precise positioning scheme can completely avoid these disadvantages. Ultrasonic precise positioning has the quality of good real-time performance and high precision, thus the control scheme of the omni-directional mobile manipulator based on ultrasonic can make up for the defects of existing control strategy. The control scheme proposed by the present project is to regard omni-directional mobile manipulator as an organic unit which can expand the moving space and improve moving flexibility. And then the advanced CAN bus technology is employed to enhance the real-time performance and consistency of communication inside control system.

Simulate the moving regularity of manipulator through model methods established by quaternions and there will be a complicated intermediate transformation matrix which can make up deficiencies of the motion simulation of the manipulator by the original ordinary model method as well as the the deficiency of disagreement in calculation. In this paper, only the realization of the module of work attendance check is given. During designing the platform, the module is divided into four parts, and each parts will be respectively presented,as a individual folder, in the resource manager of the manipulator's operation platform. Every management component in each module is composed of this four pats. Take the attendance registration in work attendance check module for example, the four parts are performed as registration, registration calibration, generating statements of registration database and entity object of registration. Registration class is the interface to the data in the database, encapsulating three properties, and using this type can achieve access to the database, and can call the other three classes; The same goes to the class of registration calibration which offers with four methods to calibrate the business rules encapsulated in the returning business to the registration class; The statement generation class also provided four methods to return the generated statements of the database to the registration class as a string; The entity object class is the new virtual table built in a virtual data set which is used for temporary storage of data. This table contains the fields of corresponding database table, and can add table properties at any time according to the needs of data entity[2].

THE OMNI-DIRECTIONAL MOBILE MANIPULATOR

Unique function of flexible movement of the omni-directional mobile manipulator and advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. So the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. Manipulators can directly stretch and move freely in the space where can hold the manipulator, accomplishing the operation task on schedule. Unique function of flexible movement of the omni-directional mobile manipulator and advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. And the key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. The situation of robot movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology.

Therefore, the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. The key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. The situation of robot movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology. Due to the deviation and delay among the three stages as information collection, transmission, and processing, this solution can not be absolutely real-time and accurate in positioning. In this article, using the ultrasonic precise positioning scheme can completely avoid these disadvantages. Ultrasonic precise positioning has the quality of good real-time performance and high precision, thus the control scheme of the omni-directional mobile manipulator based on ultrasonic can make up for the defects of existing control strategy. The control scheme proposed by the present project is to regard omni-directional mobile manipulator as an organic unit which can expand the moving space and improve moving flexibility. Figure 1 is the controlling picture of the monolithic construction of the manipulator. Two motion modes of ODMM is omni-directional walking and pivot steering shown as Figure 2.

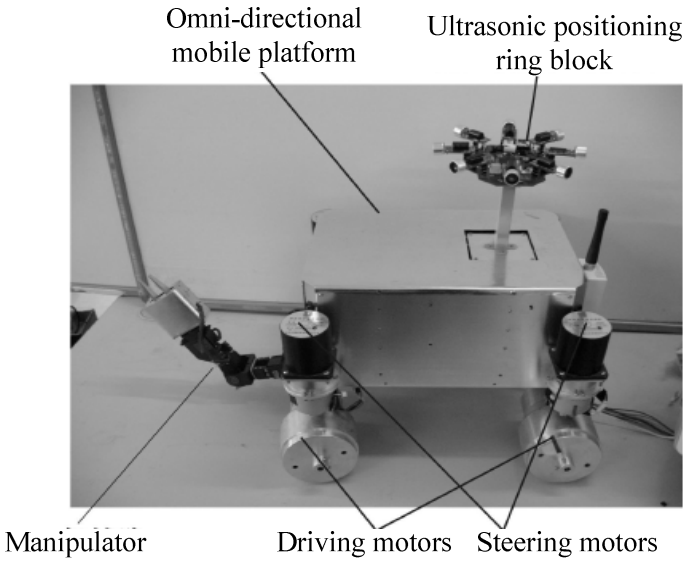


Figure 1 : The omni-directional mobile manipulator

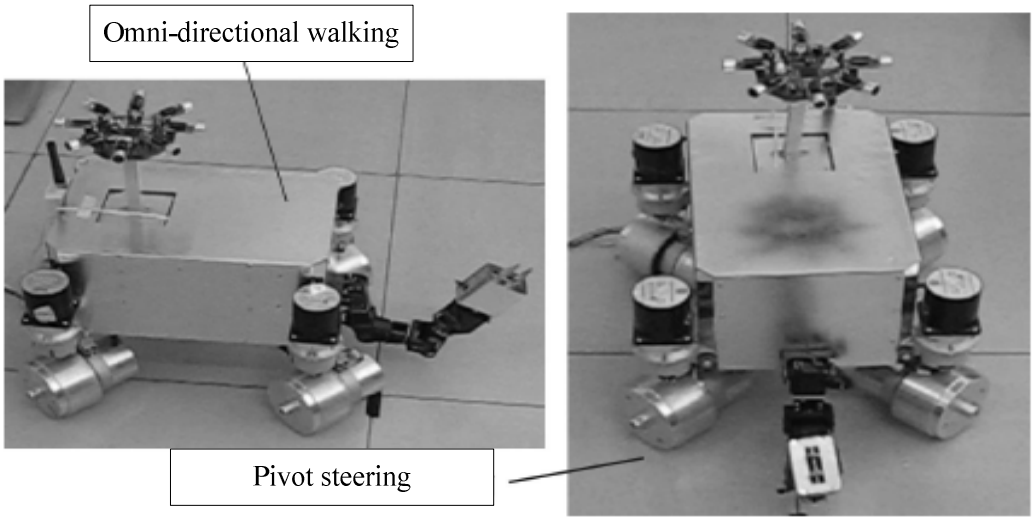


Figure 2 : Two motion modes of ODMM

MOTION CONTROL OF THE OMNI-DIRECTIONAL MOBILE MANIPULATOR

The platform location of the mobile manipulator has a great influence on whether the manipulator can accomplish the task. The situation of robot movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology. Due to the deviation and delay among the three stages as information collection, transmission, and processing, this solution can not be absolutely real-time and accurate in positioning. In this article, using the ultrasonic precise positioning scheme can completely avoid these disadvantages. Ultrasonic precise positioning has the quality of good real-time performance and high precision, thus the control scheme of the omni-directional mobile manipulator based on ultrasonic can make a good up for the defects of existing control strategy.

Manipulators can directly stretch and move freely in the space where can hold the manipulator, accomplishing the operation task on schedule. Unique function of flexible movement of the omni-directional mobile manipulator and advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. Therefore, the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. The key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. The situation of robot movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology. Due to the deviation and delay

among the three stages as information collection, transmission, and processing, this solution can not be absolutely real-time and accurate in positioning. In this article, using the ultrasonic precise positioning scheme can completely avoid these disadvantages. Ultrasonic precise positioning has the quality of good real-time performance and high precision, thus the control scheme of the omni-directional mobile manipulator based on ultrasonic can make up for the defects of existing control strategy. The control scheme proposed by the present project is to regard omni-directional mobile manipulator as an organic unit which can expand the moving space and improve moving flexibility. The relation between rotation angle φ and vehicle motor pulse value n_1 is shown as following:

$$n_1 = 80 \times \varphi / 9 \quad \textbf{(1)}$$

The relationship between the actual length of ODMM movement which is represented as S and the vehicle motor pulse value n_2 is shown in below:

$$n_2 = 32 \times S / \pi \quad \textbf{(2)}$$

To solve the problem of the low work efficiency led by the fact that the manipulator can not be controlled flexibly, the present paper puts forward a project of accurately positioning information and the timely movement controlling of the manipulator. In this set of controlling project, in order to improve the controlling precision and timing of manipulator, the CAN bus technology is used, and two operation modes of the manipulator, namely the fixed-point steering and straight running, are studied. The upper limb of vehicle has only slight variation of in moving process.

$$\theta \times \pi \times 429 / 360 = n_3 \times 100 / (200 \times 16) \quad \textbf{(3)}$$

The statement-4 can be worked out by the statement-3 through calculation.

$$n_3 = 572 \times \theta / 15 \quad \textbf{(4)}$$

The controlling value-n3 made out by actual calculation is transferred to every module, which will dive the ODMM to make a fixed-point rotation at the degree of θ after receiving data.

Motion control of the omni-directional mobile manipulator

Each of four neighbouring finger of ODMM manipulatorhas four degrees of freedom. The situation of robot movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology. Due to the deviation and delay among the three stages as information collection, transmission, and processing, this solution can not be absolutely real-time and accurate in positioning. In this article, using the ultrasonic precise positioning scheme can completely avoid these disadvantages. $\theta \geq \left[\theta_1, \theta_2, \theta_3, \theta_4\right]^T$, namely:

$$\begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} = \begin{bmatrix} \arctan\left[\dfrac{-a_y \times 10.27 + p_y}{-a_x \times 10.27 + p_x}\right] - \arctan\dfrac{(4 \times 8.3^2 - G^2)^{1/2}}{G} \\ 2 \times \arctan\dfrac{(4 \times 8.3^2 - G^2)^{1/2}}{G} \\ \arctan\left[\dfrac{n_y \times \cos\left[\arctan(n_y / s_y) - s_y \times \sin\left[\arctan(n_y / s_y)\right]\right]}{-a_y}\right] \\ \arctan(n_y / s_y) \end{bmatrix}$$

The unit of parameters in 5)is cm, parameter-G is expressed as follows:

$$G = \left[(p_y - a_y \times 10.28)^2 + (p_x - a_y \times 10.28)^2\right]^{1/2}$$

$a_x, a_y, p_x, p_y, n_x, n_v$ are the mathematical models of manipulator.

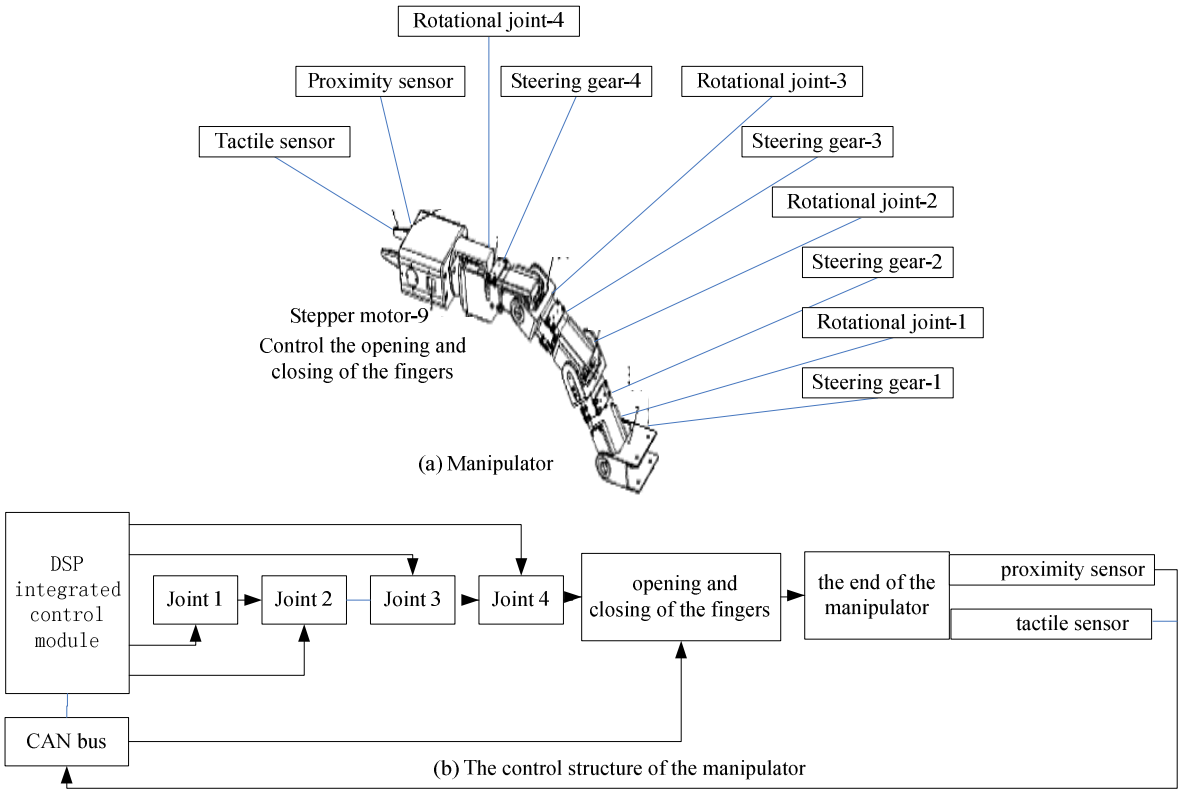


Figure 4 : The manipulator and its control structure

The common body motion modeling methods used by virtual human include kinematics, dynamics, key frame interpolation and motion capturing, each of which suitable for different application background. In order to ensure the controllability, verisimilitude and real-time performance of maintenance action, according to the different types of maintenance action of upper limb,different approaches are taken to model and encapsulate. The parameterization of key frame interpolation makes grasping action possible. Through the man-machine dialog or commanding at console board, the user can appoint a target gesture as shown in 4(b). It provides a good prerequisite for parameterization of key frame interpolation.

The planning and control of timely motion based on absolute positioning

Ultrasonic ring positioning module

In the ultrasonic absolute positioning system, an omni-directional mobile manipulator can steer free and move flexibly on the ground, as well as keep the car's overall position unchanged. Manipulators can directly stretch and move freely in the space where can hold the manipulator, accomplishing the operation task on schedule. Unique function of flexible movement of the omni-directional mobile manipulator and advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. Therefore, the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. The key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. The situation of robot movement is actually the three dimensional location information of its each part. At present, the information is collected and integrated by using sensor technology and integrate, and then problem can be analyzed and solved through image processing technology. Due to the deviation and delay among the three stages as information collection, transmission, and processing, this solution can not be absolutely real-time and accurate in positioning. In this article, using the ultrasonic precise positioning scheme can completely avoid these disadvantages. Ultrasonic precise positioning has the quality of good real-time performance and high precision, thus the control scheme of the omni-directional mobile manipulator based on ultrasonic can make up for the defects of existing control strategy. The control scheme proposed by the present project is to regard omni-directional mobile manipulator as an organic unit which can expand the moving space and improve moving flexibility. And then the advanced CAN bus technology is employed to enhance the real-time performance and consistency of communication inside control system. Therefore, it makes a foundation for the planning and control of the ODMM timely motion. The Ultrasonic ring positioning module is shown as Figure 5.

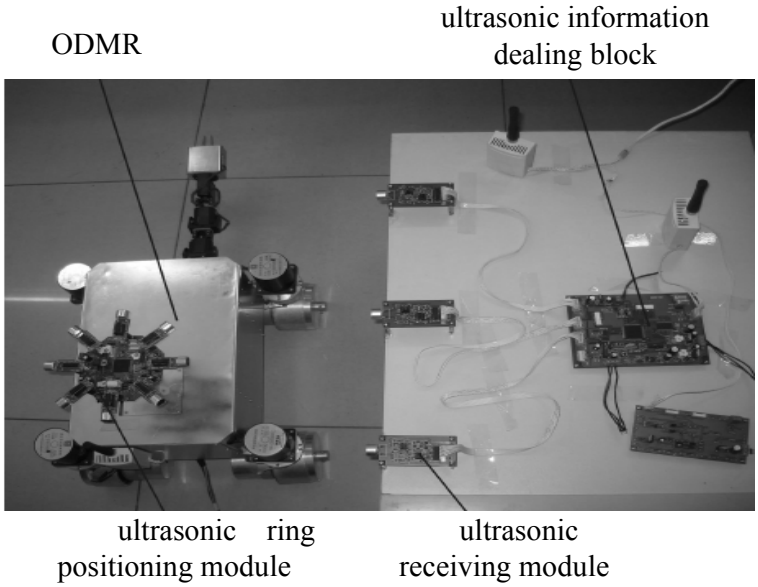


Figure 5 : Ultrasonic ring positioning module

The planning and control of timely motion based on absolute positioning

ODMM manipulators can directly stretch and move freely in the space where can hold the manipulator, accomplishing the operation task on schedule. Unique function of flexible movement of the omni-directional mobile manipulator and advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. Therefore, the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. The key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. When $y \le y_0$, the following statements can be worked out:

$$\begin{cases} x' = x_0 + d_{T_0T'} \times \sin\varphi_0 \\ y' = y_0 - T_0T' \times \cos\varphi_0 \\ \varphi' = \varphi_0 \end{cases} \quad \textbf{(6)}$$

When $y > y_0$, the following statements can be worked out:

$$\begin{cases} x' = x_0 - d_{T_0T'} \times \sin\varphi_0 \\ y' = y_0 + T_0T' \times \cos\varphi_0 \\ \varphi' = 180 + \varphi_0 \end{cases} \quad \textbf{(7)}$$

Supposing the turning angle of ODMM is δ, then:

$$\delta = \begin{cases} 90 - \arctan\left(\dfrac{y'-y}{x-x'}\right) - \varphi_0, y' \ge y, x' < x; y' < y, x' > x \\ \arctan\left(\dfrac{y'-y}{x'-x}\right) - \varphi_0 - 90, y' \ge y, x' > x; y' < y, x' < x \\ -\varphi_0, \qquad\qquad x' < x \end{cases} \quad \textbf{(8)}$$

In the above statements, the entire car body $y' < y \le y_0$ or $y_0 < y < y'$. When the action of manipulator, $y_0 > y' \ge y$ or $y_0 < y' < y$, ODMM can reach the destination. The planning and control of timely motion based on absolute positioning is shown as Figure 6.

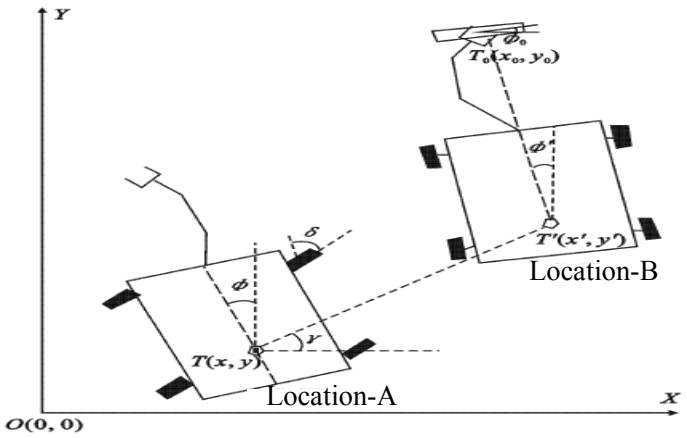


Figure 6 : The planning and control of timely motion based on absolute positioning

EXPERIMENTS ON MOTION CONTROL OF THE OMNI-DIRECTIONAL MOBILE MANIPULATOR

Experiments of omni-directional walking

These experiments are to verify the fact that this solution has the quality of good real-time performance and high precision. The project uses the ultrasonic precise positioning method which can make up the defects entirely. Ultrasonic precise positioning has the quality of good real-time performance and high precision, thus the control scheme of the omni-directional mobile manipulator based on ultrasonic can make up for the defects of existing control strategy. The control scheme proposed by the present project is to regard omni-directional mobile manipulator as an organic unit which can expand the moving space and improve moving flexibility which shown in TABLE1.

TABLE 1 : Experiments of omni-directional walking

Walking angle(°)	Course deviation(°)	Course position deviation(°)	Walking angle(°)	Course deviation(°)	Course position deviation(°)
-45	4.5	7.6	24	2.7	4.1
-24	5.6	10.3	45	1.6	2.3
0	4.3	5.4			

Experiments of pivot steering

Unique function of flexible movement of the omni-directional mobile manipulator and advanced technology it applied, has certain guiding influence on the research of flexible movement and free walking of intelligent robot. Therefore, the free motion modes of manipulator will become the development direction of the movement modes of the intelligent robots. The key to control the behavior of intelligent robots is to make a accurate collection of the robots moving situation. And the difficulty is how to measure. The details of the experiments are shown in TABLE 2.

TABLE 2 : Experiments of pivot steering

Rate/khz	Position deviation in forward steering/mm	Position deviation in reverse steering/mm
0.576	3.0	2.5
1.152	2.6	1.8
2.304	1.7	3.2

Experiments of the planning and control of timely motion based on positioning

In these experiments, some realization methods of motion library have been discussed such as designing the underlying the action simulation framework by finite state automata, realizing the encapsulation of the entire action library based on object-oriented technology, designing the underlying the action simulation framework by action machine. The command interface design of the action unit parameterization is shown in Figure7.

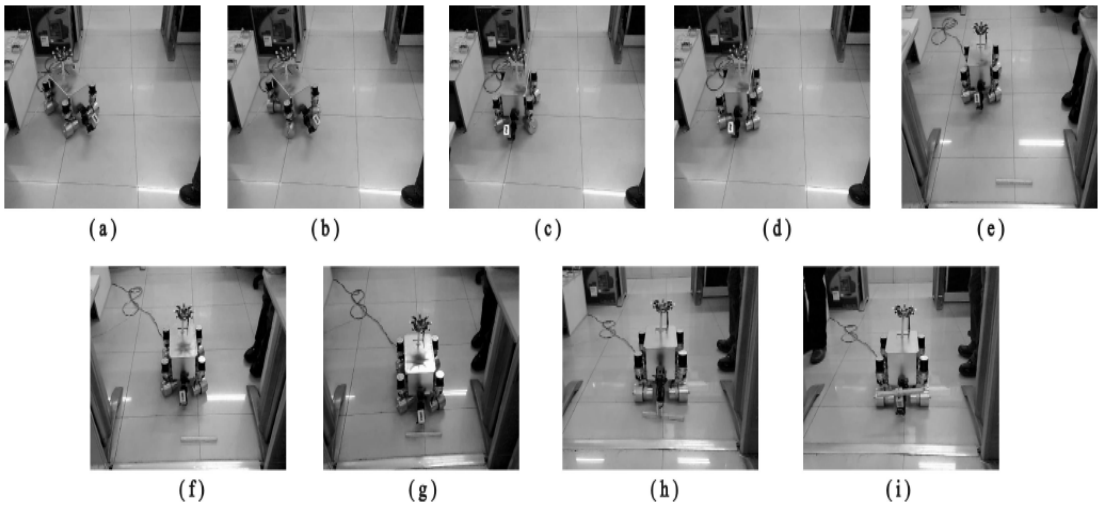


Figure 7 : Experiments of the planning and control of timely motion based on positioning

CONCLUSION

The present paper mainly introduced the integral motion controlling project of onmi-directional mobile manipulator. In this project, in order to improve the controlling precision and timing of manipulator, the CAN bus technology is used and and two operation modes of the manipulator, namely the fixed-point steering and straight running, are studied. By using ultrasonic precise positioning technology, it is ensured that the measurement of free activities of the manipulator can be controlled, thus ensuring the work efficiency of manipulator. In order to verify the correctness of the proposed scheme, and the rationality of the adopted technology, the article did three experiments on the motion of manipulators. One of them is used to prove that control scheme is correct, and the other two are used to verify that motion control of omni-directional manipulator is high precise and can position accurately. The results of the experiments have proved that the project proposed by the present paper is practical and feasible.

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