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DESIGN AND REALIZATION OF AUTOMATIC EXCHANGE STATION FOR MOBILE ROBOT

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ABSTRACT

An automatic exchange station of mobile robot is designed, and the design method of the mechanical structure and control system are put forward. The method of automatic exchanging battery is adopted, and the switching device of turn-plate structure and push-pull device of orthogonal mobile cantilevered structure are designed. The process of power exchanging is realized by the Mealy automation. The experiment results show that the station can exchange battery fast and efficiently, thus the power renewal time of the robot is greatly reduced.

Keywords: *Automatic Power Exchange, Switching Device, Push-pull Device, Mealy Automation*

1. INTRODUCTION

The energy supply of mobile robots can directly affect its work efficiency and work range, and it has become the bottleneck. Researches in this field mainly focus on independent charging method and automatic battery replacement method, in which the former needs more continuous time to charge, and can only applies to the intermittence robot [1,2], the latter is a more efficient way, and can save the charge time. However, studies on this method are less. Japan Tim Chuck Company [3] designed a battery switching device, which is in rectangle structure and all in transverse distribution to form lines. It occupied a large space in unilateral direction, and when moving the forane battery, the waiting time is long. Taiwan's Industrial Technology Research Institute [4] designed a robot power station which can be used to exchange the battery. Its functional principle is similar with literature [3], and only can exchange one group battery. Concerning the above problems, this paper introduces a design way of an automatic exchange station for the mobile robot, which adopts the automatic battery replacement method, as well as the switching device of turnplate structure and push-pull device of orthogonal mobile cantilevered structure, and the covering area is saved on condition of exchanging the same number batteries. The process of power exchanging is realized by the Mealy automation.

2. MECHANISM DESIGN OF EXCHANGE STATION

The main structure of exchange station is made up of switching device and push-pull device, as shown in figure 1:

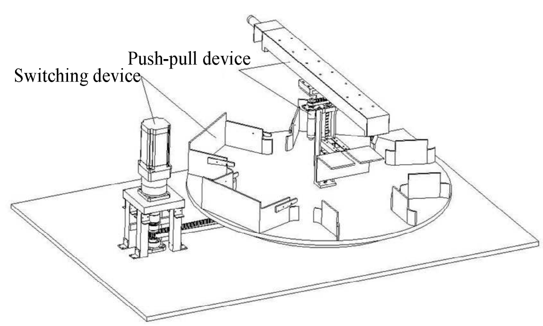

Figure.1 Diagram of Exchange Station Structure

The switching device mainly includes the transmission unit and turnplate, in which the former is made up of motor, encoder and synchronous belt, and is used to control the speed of turnplate rotation and angle accurately. On the surface of turnplate, five positions are evenly distributed: two empty positions and three charging positions, and approach switches are installed respectively to detect whether each position has power. Two adjacent vacancies are transit position and battery position， the former is used to place the low voltage battery got from the robot temporarily, and the battery position is for putting the full voltage

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battery. Only rotating an angle, switching of the two kinds of battery can be realized.

The push and pull device adopts the horizontal-vertical orthogonal mobile cantilever structure. The vertical module can move back and forth along the horizontal module, and the terminal actuator can move up and down along the vertical module. The horizontal and vertical modules are driven by the DC motor, and photoelectric switches are installed respectively to test the movement of vertical module and terminal actuator. The terminal actuator coordinates with the vertical module to achieve the pick and place action of battery.

3. DESIGN OF THE CONTROL SYSTEM

3.1 Hardware Design Of The Control System

The exchange station lays a high demand on the positions of switch device and push and pull device, thus the embedded industrial computer is used as the core control unit to build the hardware control system, as shown in figure 2:

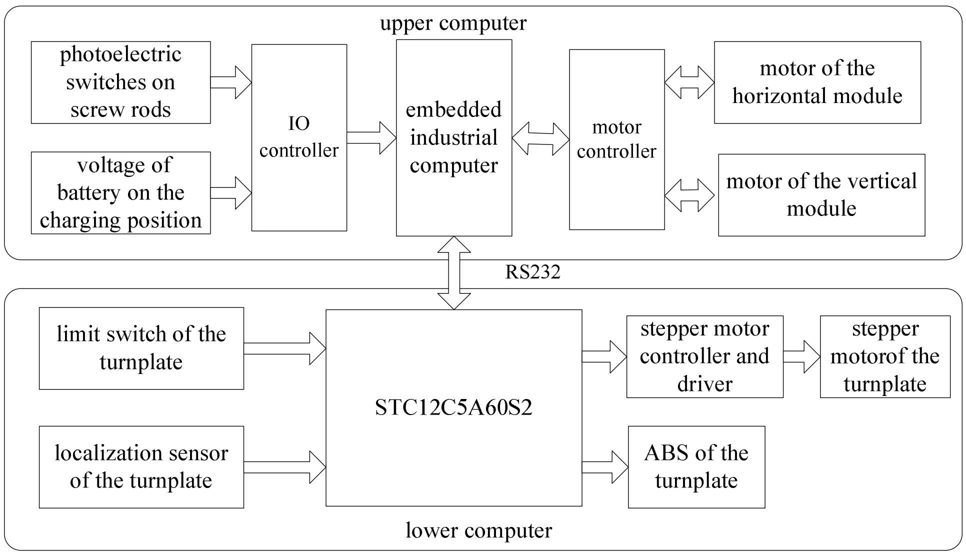

Figure.2 Diagram of the Overall Control System

The embedded industrial computer is the core control unit of upper computer, mainly uses to control the servo motor of the horizontal and vertical module, detects the information from position sensor, measures the charging battery voltage on the turnplate in real-time and makes sure the rotation target position, and sends rotation order through RS232 and receives position sensor information of the turnplate.

The lower computer is for the motion control of the turnplate, and it includes the SCM, stepper motor, the turnplate institutions and sensors. As the core of the system, the SCM is used to receive and execute the control commands sent by upper computer constantly, and gives feedback of position information to it.

3.2 Control Method Based On The Mealy Automation

The Mealy automation is adopted to realize the behavior scheduling of the exchange process. Mealy automation is a finite state machine with output function, it is a sixtuple[5]:

$$M = (Q, \Sigma, \Delta, \delta, \lambda, q_0)$$

and， Q is the non-empty finite set of the state. $\forall q \in Q$, q is a state of M , Σ is the input alphabet, Δ is the output alphabet. δ is the state transition equation, $\delta : Q \times \Sigma \to Q$. λ is the output function, $\lambda : Q \times \Sigma \to \Delta$. q_0 is the initial state.

（1）Division of State

Process of automatic battery replacement involves:

① Remove the low power battery in the robot;

② Put the full voltage battery into the robot battery warehouse;

③ Charge the low voltage battery in the charge position;

④ Put the full voltage battery in the battery position.

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Therefore, states of the process can be divided into six states: initial state, put low power batteries into transit position, put the full voltage battery into the robot, put the full voltage battery into the battery position, put the low power battery to the charging position, and institutions reset, as is shown in table 1.

Table.1 States Table

State	State description
0	initial state
1	put low power batteries into transit position
2	put the full voltage battery into the robot
3	put the full voltage battery into the battery position
4	put the low power battery to the charging position
5	institutions reset

That is, $Q=\{0,1,2,3,4,5\}$。

（2）confirmation of input and output

According to the outside input and current state, the system makes decisions and produces the output.

RDS: robot docking signal, RDS= {0, 1}, regard value 1 as the completion of robot docking; otherwise the value is 0.

TLPS: turnplate limit position signal, TLPS= {0, 1}, regard value 1 as the turnplate's reaching of initial state; otherwise the value is 0.

VLPS: vertical module limit position signal, VLPS={0,1,2}, regard value 0 as the vertical module's position that between the positive and negative limit position of the horizontal module; and value 1 represents that vertical module is located at the positive limit position; value 2 represents in the position of negative limit position.

HLPS: terminal actuator limit position signal, HLPS={0,1,2}, value 0 represents that the terminal actuator is between the upper and lower limit position of a vertical module; Value 1 represents that it is in the lower limit position; Value 2 represents it is in the upper limit position.

CPVCS: charging position vacancy check signal, CPVCS= {0, 1}, value 1represents the charging position has battery; otherwise the value is 0.

TPVCS: transmit position vacancy check signal, TPVCS= {0, 1}, value 1shows there is battery; otherwise the value is 0.

BPVCS: battery position vacancy check signal, BPVCS= {0, 1}, value 1 shows there is battery in the battery position; otherwise the value is 0.

CVM: measurement of charging voltage, CVM = {0, 1}, value 1 represents the charging position has full charged battery; otherwise the value is 0.

Table.2 State Shift Table

NO.	States	conditions											Output action
		docking	Limit switch			Vacancy check			Voltage check	Position check			
		RDS	TLPS	VLPS	HLPS	TPVCS	BPVCS	CPVCS	CVM	TP	VMP	TAP	
0	Initial state	1	1	0	0	0	1	×	×	0	0	0	Take battery
1	Low power battery get into the transmit position	1	0	0	0	1	1	×	×	0	1	1	send battery
2	Full harged battery get into the robot	1	0	0	0	1	0	×	×	2	2	1	Charge battery
3	Low power battery get into the charging position	×	0	0	0	0	0	1	1	1	1	0	Prepare battery
4	Put battery into the battery position	×	0	0	0	×	1	×	×	2	1	0	institutio n reset
5	institution reset	×	1	0	0	0	1	×	×	0	0	0	Wait to get the battery

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TP: turnplate position, TP= {0, 1, 2}, shows the terminal actuator in the transmission, charging and battery position of the positive turnplate respectively.

VMP: vertical module position, VMP= {0, 1, 2}, shows the vertical module is in the end, center and primacy position of the horizontal module.

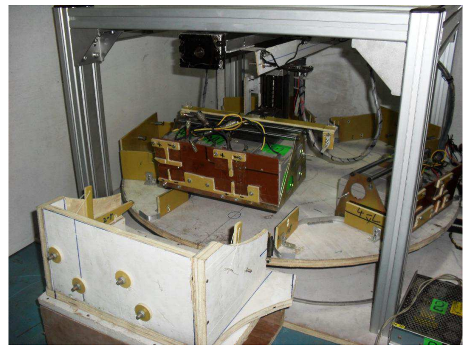
TAP: terminal actuator position, TAP= {0, 1, 2}, represents the terminal actuator is in the lower, center and upper position of the vertical module.

The output includes six actions: take battery, send battery, charge battery, prepare the battery, institution reset and wait to take the battery.

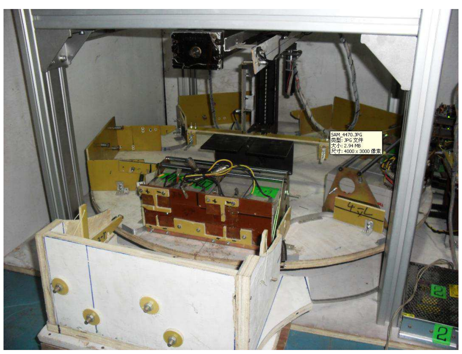
（3）Conformation of the State Shift Table

Based on the above Mealy automation model, table-driven algorithm is adopted [6], as shown in table2

(a) robot docking

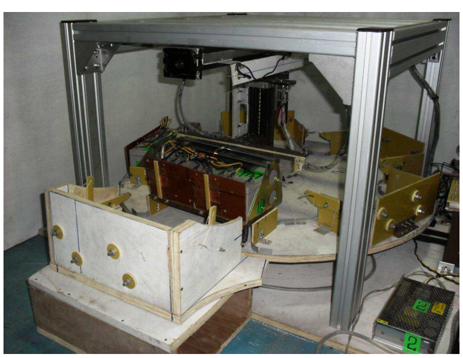


(b)lift the internal battery pack of robot

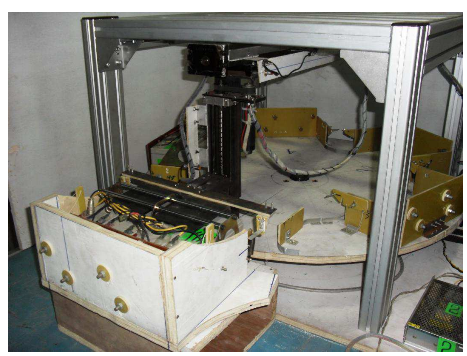


(c)put the low power battery into the transmit position

(d) battery position directs at the robot



(e) lift the full voltage battery pack



(f) put the full voltage battery pack into the robot

Figure3. Overall Process of Battery Replacement in the Exchange Station

4. EXPERIMENTAL RESULTS AND ANALYSIS

According to the above design scheme, the exchange station prototype is manufactured and the experiment is carried out, as shown in figure 3.

Figure 3(a) simulates the docking robot, and the transmit position is opposite to the robot battery

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storehouse. There are full charged battery in the battery position; Figure 3(b), push-pull device of terminal actuator lifts the battery; Figure 3(c), vertical module of the push-pull device moves back along the horizontal modules to the center position, and the terminal actuator moves down along vertical modules to put the low power battery into the transmit position, then the vertical module moves back to a safe place; Figure 3(d), the turnplate turns 72 degrees in clockwise, and the battery position directs at the robot; Figure 3(e), terminal actuator lifts up the full voltage battery; Figure 3(f), put the full voltage battery into robot battery warehouse, and complete the replacement of low power battery and full voltage battery.

After the robot's leave, the station will transfer the low power battery into the charging position to charge it, and check whether there is full charged battery at the same time. If there is, it should be transferred to the battery position to prepare for the next battery replacement. The experiment shows that the renewal time of this stand is about 32 s.

5. CONCLUSION

This paper introduces an efficient automatic exchange station, and illustrates the mechanical structure and control system, and realizes the automatic renewal process through the Mealy automation. The system has the following characteristics: (1) it can save the occupy area by changing the traditional switching device; (2) the push-pull device and switching device collaborate with each other to realize the battery replacement of robot, which can greatly reduce the waiting time of the robot.

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