The Eighteenth International Symposium on Artificial Life and Robotics 2013 (AROB 18th '13),
Daejeon Convention Center, Daejeon, Korea, January 30-February 1, 2013

Design a Feasible Docking Station for Mobile Robots

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Abstract: The article develops a docking station that has feasible movement and rotation function for mobile robots. The docking station contains a docking structure, a limit switch, a charger, a power detection module and a wireless RF module. The docking structure is designed with one active degree of freedom and two passive degrees of freedom. It rotates in the Z-axis, and uses compression spring to move for various docking condition. The weight of the docking station is almost 6 kg, and its length, and height, and width are 70cm, 50cm and 80cm. The maximum rotational angle and horizontal offset are 30 degree and 2 cm respectively. The power detection module is controlled by HOLTEK microchip. We calculate the power values using redundant management method, and isolate the error values using statistical signal prediction method, and execute the auto-recharging processing for mobile robots. The processing can enhances the successful rate to guide the mobile robot moving to the feasible docking station from various directions. In the experimental results, the power of the mobile robot is under the threshold value. The mobile robot searches the landmark of the docking station using laser range finder (SICK). The laser range finder guides the mobile robot approach to the docking station, and uses the adequate docking angle to be approach to the station.

Keywords: mobile robots, wireless RF module, HOLTEK microchip, redundant management method, statistical signal prediction method, laser range finder

I. INTRODUCTION

Mobile robots have been widely applied in many fields such as factory automation, dangerous environment detection, office automation, hospital, entertainment, space exploration, farm automation, military, education and security system and so on. The power of the mobile robot is under the threshold value for working in long time. The mobile robot executes auto-recharging processing; otherwise users can not control the mobile robot, and some dangerous event may be happened.

We have designed a power detection and diagnosis module applying in the mobile robot using HOLTEK microchip [1,2]. The module can detect multiple powers simultaneously, and extend the interface function to transmit the data to the main controller of the mobile robot via series interface, and reduce detection error using redundant management method and statistically method, and predicts the residual power to work [3].

In the past literature, many researches have been proposed power detection methods. Malaiy and Su use I_{DD} testing and estimating the effects of increased integration on measurement resolution [4]. Frenzel proposed the likelihood ration test method applying on power-supply current diagnosis of VLSI circuits [5]. Song presented the development and characterization of a surveillance robot with automatic docking and recharging capabilities using mobile wireless sensor network gateway for home security [6]. Oliveira proposed a method based on the Extended Kalman Filter (EKF) to estimate the batteries state of charger [7]. Keshmiri proposed an opportunistic control approach to address the multi-robot, multi-rendezvous recharging problem. The control strategy adapted attempts to take advantages of both centralized and distributed methodologies [8]. How to design a general charging structure is an important problem for mobile robots. The paper develops the feasible docking station that has widely docking angle.

II. SYSTEM ARCHITECTURE

The auto-recharging system is shown in Fig. 1 to be classified two parts: one is designed to supply and detect power for target device. The other receives the power to be a mobile robot. In the docking station, there are a connection structure, a limit switch, a landmark, a power detection module, a wireless RF module and a charger. The landmark can guides the mobile robot to find out the docking station using laser range finder. The power detection module can detects and controls the current output, and decides the status of the charging current, such as over loading (short), no current (shutoff) or normal current. The limit switch detects the mobile robot to touch the docking station or not. The wireless RF module can communicates with the mobile robot, and transmits and receives the real-time signals of the auto-recharging processing. In the mobile robot, there are a charging connection structure, a laser range finder, a wireless RF module, an auto-switch, a power detection module and power system.

The mobile robot has the shape of cylinder and its diameter, height, and weight are 40 cm, 60 cm, and 30 kg, respectively. The robot is equipped with an IPC (Industry Personal Computer) as the main controller. The power detection module is embedded in the docking station and the mobile robot. The controller of the module is HOLTEK microchip, and computes the exact power using redundant management method. In the mobile robot, the module measures the exact power using four current sensors, and isolates the faulty measurement values, and predicts the residual power of the power system.

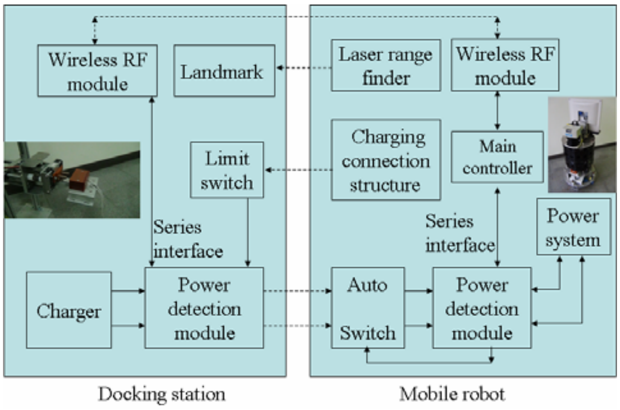


Fig. 1 The auto-recharging system

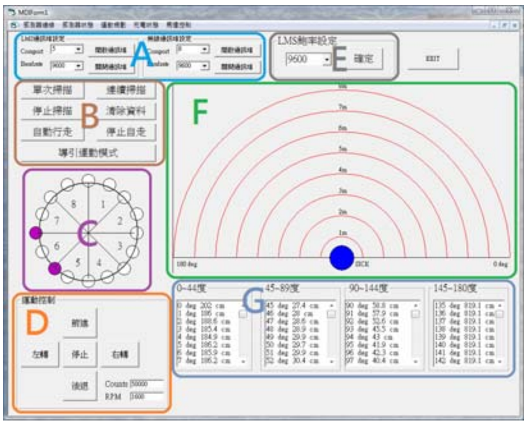


Fig. 2 The user interface of motion planning

The user interface is the motion planning of the mobile robot to be shown in Fig. 2, and contains eight parts. The label "A" can programs the communication protocol of the laser range finder and wireless RF interface, and sets the communication port is 3 for wireless RF interface. The label "B" is control command for the mobile robot, and sets the motion mode of the mobile robot. The label "C" displays the information of the IR sensors and the compass. Users control the mobile robot moving forward, backward, turn right, turn left and stop to be shown in the label "D". The label "E" sets the baud-rate of the laser range finder. The label "F" displays the direction of the docking station. The outlook of the detected environment is plotted in the label "G" by the laser range finder. The relation information of the LRF is shown in the label "H".

The user interface of the auto-recharging system contains five parts to be shown in Fig. 3. The label "A" displays the measured values of current and voltage, and computes the estimation value and average value of the power system. The label "B" displays the charging processing of the auto-recharging system, and contains alarm, start charging and finished. The label "C" displays the real-time information in the processing. Users want to stop and restart the charging processing to shown in the label "D". The label "E" plots the current curve and the voltage curve of the charging processing.

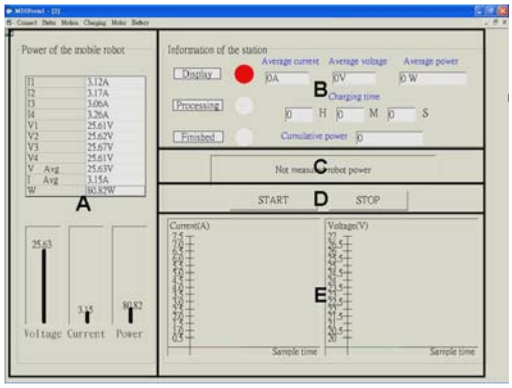


Fig. 3 The user interface of auto-recharging system

III. DOCKING STATION

The overview of the docking station is shown in Fig. 4. The docking station provides two contact points to connect the charging connection structure of the mobile robot. The docking station is designed with two passive DOF (Degree Of Freedom) and one active DOF. In the two passive DOF, it rotates on the Z-axis, and uses compression spring to move on the x axis for various docking condition. The active DOF rotates on z axis, and controls the connection pins moving forward to touch the connection structure of the mobile robot. The connection structure of the mobile robot is mounted on the back side of the mobile robot, and places on the same side of the laser range finder. The prototype of the docking station is shown in Fig. 4.

The recharging adapters of the mobile robot are at the inside of the holes. Each hole is shaped as a cone in order to help the docking smoothly. Since both the connection pins and adapters are rigid, the docking station is designed for providing compliance for reasonable robot docking angle and offset. When the mobile robot is approach to the docking station with offset and docking angle, the guiding stick mounted on the docking station functions to guide the recharging pins for inserting into the adapters. The maximum rotational angle and horizontal offset are 30^0 and 2 cm respectively.

In the fig. 5, the mobile robot moves to the docking station with offset angle. The guiding stick can't touch the center of the connection structure, and rotates on the z axis to guide the connection pins to insert into the adapters. In the other condition, extension sprints are used to bring the recharging pins backing to the center after the robot disengages. A little entry offset and angle are allowed when the robot is in the docking process. The experimental result is shown in Fig. 6.

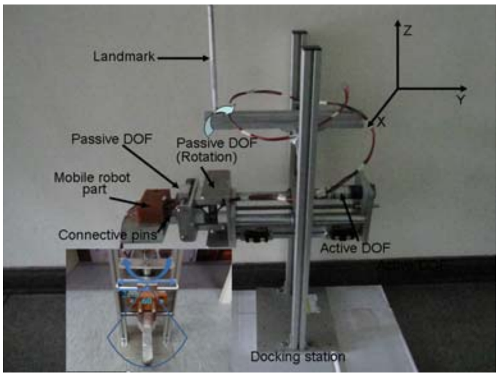


Fig. 4 The docking station

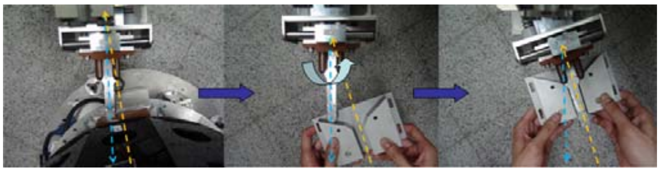


Fig. 5 The docking processing with offset angle

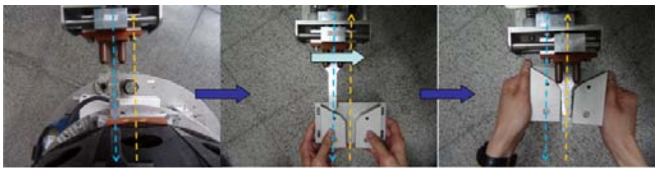


Fig. 6 The docking processing with offset distance

IV. EXPERIMENTAL RESULTS

The mobile robot moves autonomously in the free space, and uses the power detection module to detect power variety, and calculates the residual power. Then it computes the residual time to be under the threshold time. The user interface of the mobile robot displays to execute the auto-recharging processing. The mobile robot searches the docking station using laser range finder according to the landmark. The landmark is fixed on the top of the station to be shown in the right side of Fig. 7. In general, the docking station is fixed on the front side of the wall. The landmark is more near to the mobile robot than the wall. The mobile robot decides the position of the station according to the information of the laser range finder to be shown in Fig. 7.

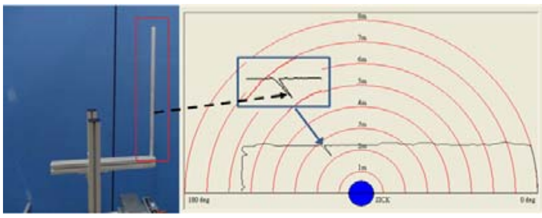
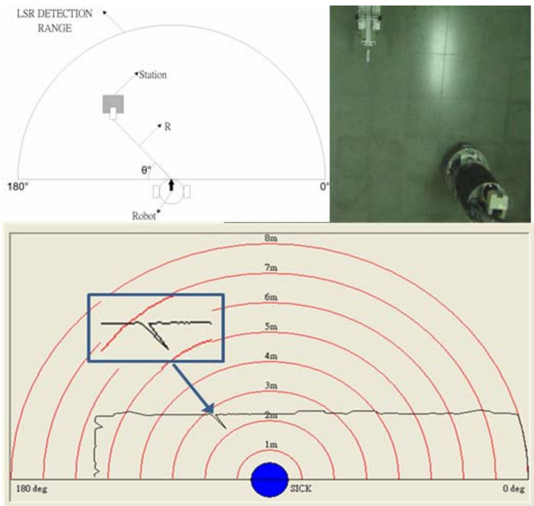


Fig. 7 The landmine detection

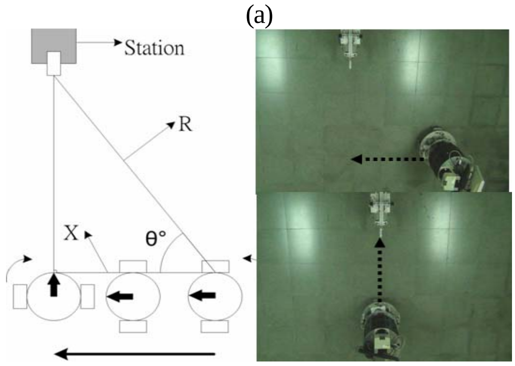
We explain the docking processing for two cases. The first case, the mobile robot locates on the right side of the station, and detects the landmine on the left side to be shown in Fig. 8(a). It computes the relation distance using the equation:

$$x = R\cos\theta \qquad (1)$$

The parameter R is the distance far from the docking station. The mobile robots turns left θ, and moves the distance x. Then the mobile robot turns right 90^0 moving approach to the station. The experimental scenario is shown in Fig. 8(b). In the other case, the mobile robot locates on the right side of the docking station. The mobile robot executes the similar processing moving to the station. The docking station is detected by the mobile robot, and locates on the right side. The mobile robot turns left θ moving the assigned distance. Then the mobile robot turns left 90^0 moving approach to the station to be shown in Fig. 9.

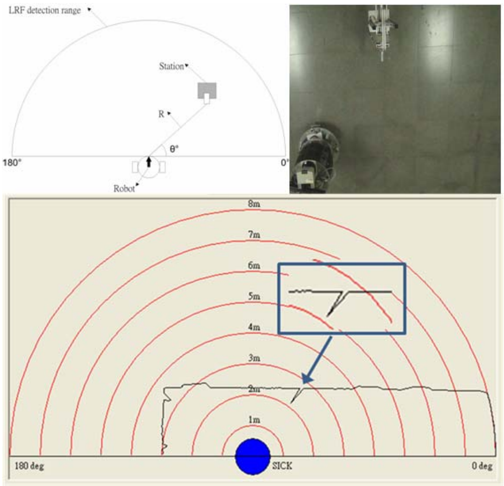


(a)

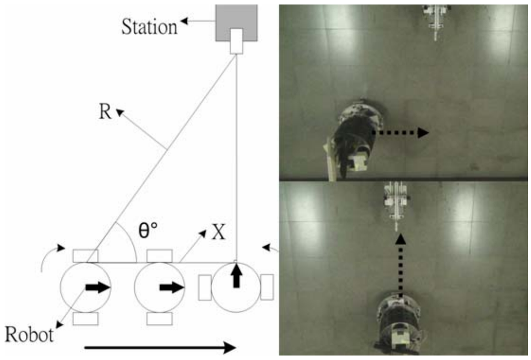


(b)

Fig. 8 The docking processing from right side



(a)



(c)

Fig. 9 The docking processing from left side

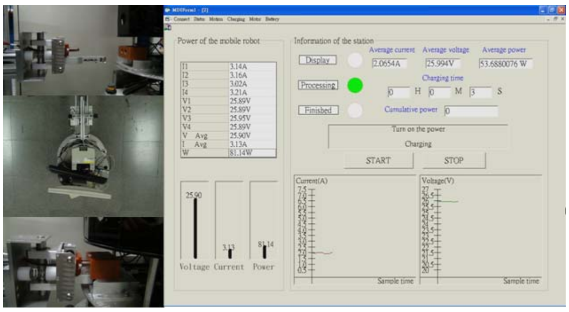


Fig. 10. The charging processing

The mobile robot moves to the docking station, and touch the connect pins and the limit switch to be shown in the left side of Fig, 9. The docking station transmits RF signal to the mobile robot. The mobile robot must stops, and prepares to execute the charging processing. Then the mobile robot turns on the auto-switch to receive the charging current. The docking station supplies the charging current to the mobile robot. The user interface displays green label on "Charging" to present the docking station is successful, and plots the current curve and voltage curve, and computes the charging time for the mobile robot. The charger of the station provides the power to the mobile robot. The experimental result is shown in Fig. 8 (a) and (b). Then the power detection module measures the charging current to be about 2.5A. The user interface of the mobile robot displays the charging processing to be shown in Fig. 10.

V. CONCLUSION

We have developed a feasible docking station of the auto-recharging system for the mobile robot, and finished a series auto-recharging processing. The docking station uses the landmark to guide the mobile robot, and adjusts two passive axis to connect the charging pins of the mobile robot. The mobile robot uses laser range finder to search the docking station, and moves to the docking station according to the landmark. We program a new auto-recharging processing to enhance the successful rate of the docking behavior for the mobile robot. In the docking processing, the system detects the charging current of the docking station and the mobile robot. The docking station communicates with the mobile robot using wireless RF interface.

ACKNOWLEDGMENT

This work was supported by the National Science Council of Taiwan, (NSC 101- 2221- E-224-007)

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