A Development of Home Mess-Cleanup Robot

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Abstract: In this paper, a Home Mess-Cleanup Robot(HMR), which has a practical function of the automatic mess-cleanup, is developed. The vacuum-cleaner had made the burden of house chore lighten but the operation labour of a vacuum-cleaner had been so severe. Recently, the cleaning robot was producted to perfectly solve the cleaning labour of a house but it also was not successful because it still had a problem of mess-cleaning, which was the clean-up of big trash and the arrangement of newspapers, clothes, etc. The cleaning robot is to just vacuum dust and small trash but has no function to arrange and take away before the automatic vacuum-cleaning. For this reason, the market for the cleaning robot is not yet built up. So, we need a design method and technological algorithm of new automatic machine to solve the problem of mess-cleanup in house.

It needs functions of agile automatic navigation, novel manipulation system for mess-cleanup. The automatic navigation system has to be controlled for the full scanning of living room, to recognize the absolute position and orientation of the self, the precise tracking of the desired path, and to distinguish the mess object to clean-up from obstacle object to just avoid. The manipulator, which is not needed in the vacuum-cleaning robot, must have the functions, how to distinguish big trash to clean from mess objects to arrange, how to grasp in according to the form of mess objects, how to move to the destination in according to mess objects and arrange them. We use the RFID system to solve the problems in this paper and propose the reading algorithm of RFID tags installed in indoor objects and environments. Then, it should be an intelligent system so that the mess cleaning task can be autonomously performed in a wide variety of situations and environments. It needs to also has the entertainment functions for the good communication between the human and HMR. Finally, the good performance of the designed HMR is confirmed through the results of the mess clean-up and arrangement.

Keywords*: Home Mess-Cleanup Robot (HMR), Autonomous Navigation, Manipulator, Object Detection System, RFID Sensor*

1. INTRODUCTION

The current robot requires the advanced technology, such as soft computing, human-friendly interface, interaction technique, speech recognition, object recognition etc., unlike the industrial robot in those days. RT(Robot Technology) is including these advanced techniques, and is full of promise in 21th century as IT(Information Technology), BT(Bio Technology) and NT(Nano Technology). Especially, Home Service Robot, a kind of personal robot for work, amusement and education of home, are world-widely studied in these days. A product of home service robot is the cleaning robot. The cleaning robot is an electric home appliance, which was developed from the wheel-based mobile robot in the same modification method as a vehicle robot of factory automation and a guidance robot.

The vacuum-cleaner had been developed in 1950's to help the manual cleaning of a house, which had been most important in house chore. It had made the burden of house chore lighten but the operation labor of a vacuum-cleaner had been so severe. Recently, the cleaning robot was producted to perfectly solve the cleaning labor of a house but it also was not successful because it still had a problem of mess-cleaning, which is the clean-up of big trash and the arrangement of newspapers, clothes, etc. The cleaning robot is to just vacuum dust and small trash and has no function to arrange and take away before the automatic vacuum-cleaning. For this reason, the market for the cleaning robot is not yet built up. So, we need a design method and technological algorithm of new automatic machine to solve the problem of mess-cleanup in house. In this paper, a Home Mess-Cleanup Robot(HMR), which has a practical function of the automatic mess-cleanup, is developed.

Home Mess-cleanup Robot is not work in the fixed task such as industrial robot but have to work in much more flexible and various environments than the vacuum-cleaning robot. It needs functions of agile automatic navigation, noble manipulation system for mess-cleanup. The automatic navigation system has to be controlled for the full scanning of living room, to recognize the absolute position and orientation of the self, the precise tracking of distinguish the mess object to clean from obstacle object to just avoid. The manipulation system, which is not needed in the vacuum-cleaning robot, must have the functions, how to distinguish big trash to clean from mess objects to arrange, how to grasp in according to the form of mess objects, how to move to the destination in according to mess objects and arrange them. In this paper, a Mess-cleanup Robot, including both the automatic navigation system and the agile manipulation system, is optimally implemented. Then, it should be an intelligent system so that the mess cleaning task can be autonomously performed in a wide variety of situations and environments. But, it was not easy for the robot to distinguish all objects. The HMR uses RFID (Radio Frequency Identification) to perfectly distinguish every object in this paper. We assume that every object and environments of In-door have optimally RFID tags. The reading algorithm of the tags on the objects and environments is proposed in this paper.

The technological concept of new machine, Home Mess-cleanup Robot, is given in the section II. It is to explain about general system configuration such as actuating, sensing, mechanical design and control for the HMR's navigation. Also, it is to propose the general algorithm such as obstacle

avoidance, object segmentation, gripping and arrangement for the HMR's manipulation of mess objects. In the section III, A new design of Home Mess-Cleanup Robot is explained. A detection algorithm and a self localization using RFID are proposed in this section. The experimental setup of the HMR is given in the section IV. Finally, the good performance of the newly designed the HMR is confirmed through the results of the mess clean-up and arrangement.

2. TECHNOLOGICAL CONCEPT OF HMR

Recently, the cleaning robot was developed to perfectly solve the cleaning labor in a house. But the cleaning robot has just an autonomous vacuum-cleaning function. It also is not successful because it still has the problem of mess-cleanup, which is the cleaning of big trash and the arrangement of newspapers, clothes, etc. The cleaning robot is to just vacuum dust and small trash. It has no function to arrange and take away before the automatic vacuum-cleaning. Therefore, we need a design method and technological algorithm of new automatic machine to solve the problem of mess-cleanup in house. In this paper, a Home Mess-Cleanup Robot(HMR), which has a practical function of the automatic mess-cleanup, is developed. The system configuration of a home mess-cleanup robot is given in the fig. 1.

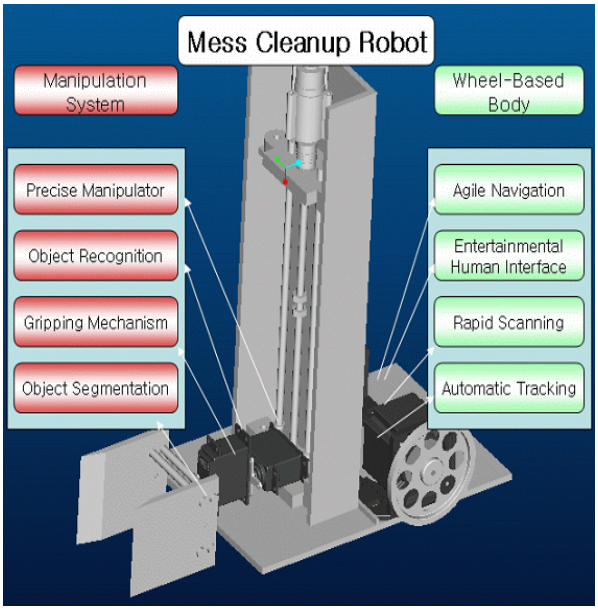

Fig. 1 HMR's System Configuration

A mess-cleanup robot system is divided into two main parts. The mess-cleanup robot is autonomously navigated more precisely than the conventional cleaning robot. The cleaning robot moves according to a wall or scans in a fixed pattern. The navigation method is enough to vacuum dust and small trash, but is not to clean and arrange the mess. Because the mess-cleanup robot have to move to the destination spot with the target object after gripping the one on the contrary to the conventional cleaning robot. Its automatic navigation system has to be controlled for the full scanning of living room, to recognize the absolute position and orientation of the self, the precise tracking of the desired path, and to distinguish the mess object to clean-up from obstacle object to just avoid.

The mess-cleanup robot has to be able to elaborately manipulate the target object. That is to exactly detect the target object, to correctly grasp the one, to accurately arrange it in the destination spot. To do that, the manipulator has a powerful detection system and a higher degree of freedom. Also, it must have a function lifting the object to arrange in a high destination spot. After all, the mess-cleanup robot is much more agile and intelligent system than the conventional cleaning robot. The manipulation system, which is not needed in the vacuum-cleaning robot, must have the functions, how to distinguish big trash to clean from mess objects to arrange, how to grasp in according to the form of mess objects, how to move to the destination in according to mess objects and arrange them. In this paper, a Mess-cleanup Robot, including both the automatic navigation system and the agile manipulation system, is optimally implemented.

Especially, its detection and navigation system should be intelligent. Or, it should be an intelligent system so that the mess cleaning task can be autonomously performed in a wide variety of situations and environments. It makes a machine quite intelligent to use RFID tags and reader.

Home Mess-Cleanup Robot has object detection system. The vision system has been used in the most method for the object detection system. But the number of data in the vision system is too much to simply use for the detection of a wide variety of objects. Agile detection is so difficult. So, we use RFID system for HMR to detect objects for mess-cleanup. A RFID reader system is designed on the HMR. The RFID tags is taped on every object in the house. Actually, they is planned to be taped on all of commercial products because the price of the tag is descending so much. This detection system using the RFID has a promising future. A scanning algorithm of the taped tags is proposed in this paper and the results is connected with a detection algorithm. Finally, HMR can make a decision of an object.

The fig. 2 is a scenario for the HMR to process a task. First, it navigates for the scan of a living room. If it comes across an object, it processes the avoidance algorithm. If it is an object, it processes the mess-cleanup algorithm

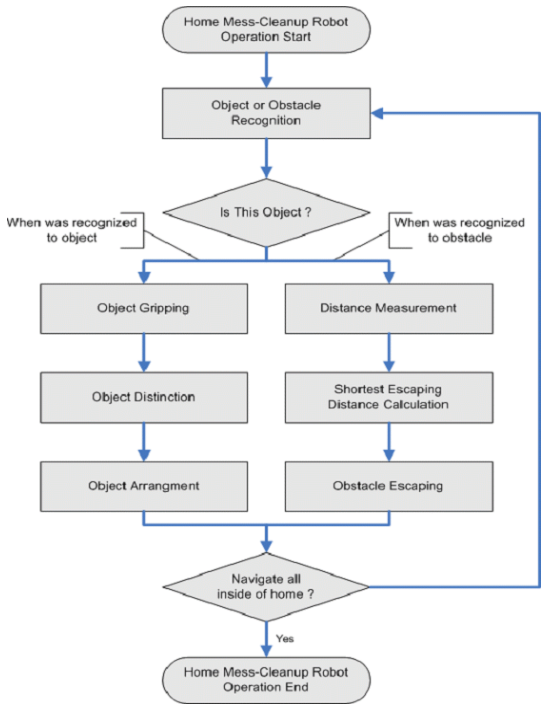

Fig. 2 A Processing Scenario of the HMR's Task

3. A DESIGN OF HOME MESS-CLEANUP ROBOT

This paper designs and embodies a Home Mess-cleanup Robot. Home Mess Cleanup Robot system designed in this paper is given in the fig. 3.

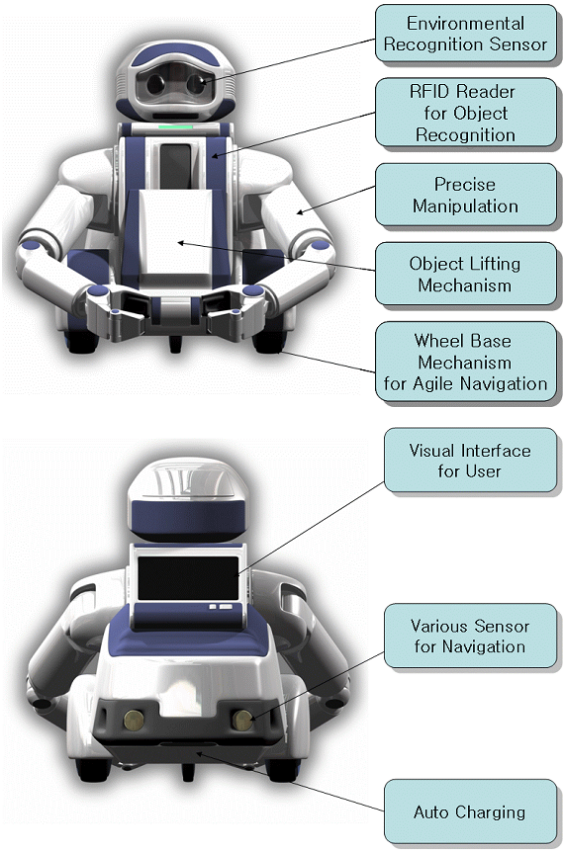

Fig. 3 A Full Configuraton of Home Mess Cleanup Robot

HMR has a mess-cleanup function and an entertainment function. The mess-cleanup function is divide into the navigation function and object-handling function. The navigation system is designed into wheel-based mobile robot. Various sensors, including vision system, is used for the localization of navigation. The object-handling system consists of two arm(manipulators) and object detection system. The manipulator, which has 6 DOF(Degree of Freedom), is shown in the Fig. 4. But it almost free from the load because it does not move an object but the object-lifting system moves. The manipulator just helps for the lifting system to put an object on the shelf.

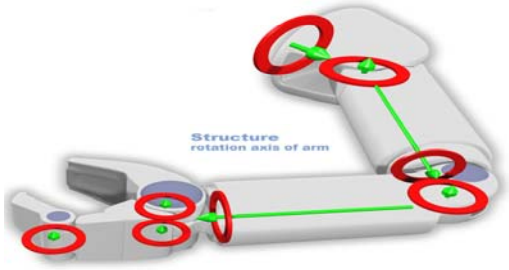

Fig. 4 Structure and Rotation Axis of Arm

HMR can get hold of any objects using the robot arm of many joints. It can move up and down an object using the lift system. Especially, it can get hold of an object in the narrow space and an object regardless of any form and quality of the material through flexible power of arm gripper.

The biggest problem is detection of the target object and self localization of the HMR in the process of mess-cleanup. This paper solves them through the RFID system. We suggest a new way of implementing HMR localization and object discrimination using RFID tags. There have been a few attempts of applying RFID technology in robot localizations.[4] It seems a valuable replacement to the conventional sensing technologies such as razor and ultrasonic sensing, because it is free from the line-of-sight problem most other sensing techniques are having trouble with. However, there is a problem applying RFID sensing in the same way other methods are used for localization, because the triangulation of the conventional localization does not work with RFID. For this to work, the distance between a sensor and a sensed object needs to be accurately measured, but today's RFID technology does not provide enough accuracy in the distance measurement. The best result so far, even after applying statistical filters such as Monte-Carlo, gives an average error of 0.77 feet in localization, which is not quite acceptable to the robot navigation.[5]

Therefore, in our implementation, we place an RFID reader (with an RF antenna installed internally) onto HMR and prepare a floor installed with a number of RFID tags, each of which possesses coordinate information of itself. With such a setting, HMR may acquire quite accurate coordinates during navigations, because the localization error depends only on dimensions of the tag and the reader, not on the distance between them. Real-time updates of the HMR coordinates are possible as the HMR navigates through the floor, so that overall performance of the HMR navigation and the object discrimination will be enhanced. This is not the first application of RFID tag installed floor to the navigation. There is the NaviGeta project[4] which utilizes RFID floor, on which a person navigates wearing shoes equipped with an RFID reader. However, this study does not address the issue on how and how many tags we should distribute to the floor to achieve effective navigations. In this study, we not only implement an RCP navigation system based on RFID, but also suggest a way to determine the efficiency of tag arrangement, tag granularities for the RFID floor and the optimization of tag attachment for the object discrimination.

In order to implement self-localization controller for HMR, we adopted the RFID technology. Not like other conventional sensors, RFID readers do not suffer from the line-of-sight problem. It can trivially provide ID information of the sensed objects as well, so that the technology is very well suited for many ubiquitous computing application such as the robot navigation we are interested in the study.

In this paper, we describe our RFID-based implementation of self-localization controller and suggest a way of improving the effectiveness of navigation by varying RFID tag arrangements on the floor. In this implementation, we make HMR know of its own coordinate through RFID sensing. For the purpose, we place a small RFID reader integrated with an RF antenna onto HMR. On the in-door floor, where the navigation is to take place, we place multiple RFID tags and associate each tag (tag ID) with a coordinate. This information is then stored into the back-end DB. During an actual navigation, as the HMR detects a tag, its ID is converted back to a coordinate at the DB, and it is fed back to the Trajectory

Controller for further control of the HMR navigation.

There may be many sensible ways of placing RFID tags to the floor and attaching it to the object. However, it may be easier to prepare tiles of the same fashion and assemble them to produce a navigational floor. This is the way we prepare an in-door floor in this implementation, so that once we decide on the tag arrangement for one tile, the rest of the floor construction is easy. The simplest way of arranging RFID tags on a tile is to place 4 tags in a square. Another way might be the one suggested in [4]. There are higher possibilities of missing tag detections during navigation. However, possibilities of missing tags in both cases are same. Therefore, we suggest the "tilted-square" placement of tags. As we can this has the lowest possibility of missing tag detections during navigation. Any straight-line movement of HMR will be easily detected with such an arrangement.

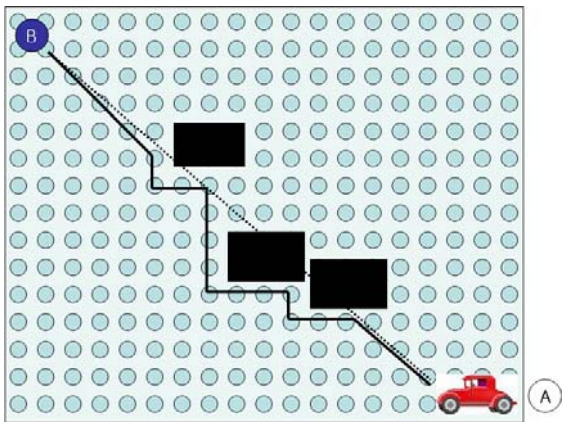

Fig. 5 Navigation Algorithm of HMR using RFID

The small points of the Fig. 5 show RFID tags and each tag can support the absolute coordinates for the navigation of the HMR A simulation program for testing the effectiveness of various tag arrangements of the RCP is given in belows. In this algorithm, users may specify various navigational parameters. Some of more important parameters are:

- Tag arrangements
  " Square", " Parallelogram", " Tilted Square", and " Random" arrangements can be chosen.
- Tag granularities
  Four tags per tile in all cases. By adjusting the size of the tile (hence the distance between tags), we can control the tag granularity.
- Read range of the tag and the reader
  Users may define these values. Because there are so many different types of tags and readers in the market, we wanted to make this simulation as general as possible. It is not only applicable to our HMR project, but also should be useful to the construction of RFID floors of many other USN applications.
- Other parameters
  Users may also specify values for departure/destination coordinates, HMR velocity, posture adjustment time, and the angular error-rate of wheels.

4. EXPERIMENT AND RESULTS

Home Mess Cleanup Robot's experiment environment is such space as the human life. When the HMR works, there are so many limitations. An emulated living Room was made for the experimental set-up of HMR in this paper. The living room was sized by 1800mm X 1800mm. A main obstacle is crossing in center of the living room and its height is 50mm and its length is 900mm. A severe mess-up situation was established. The experimental set-up in a living room is shown in the Fig. 6.

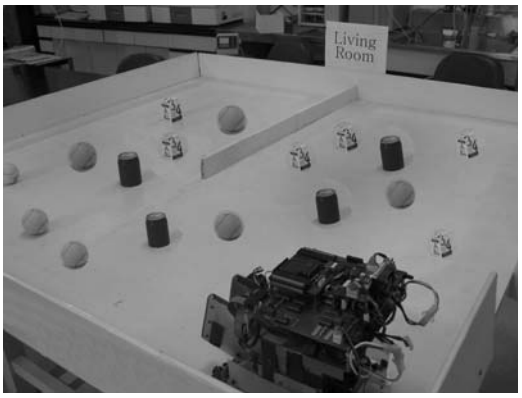

Fig. 6 The Emulated Living Room

In this experimental set-up, the living room is messed up using the various of objects. The cylindrical can and the rectangular milk-pack are used for the big garbage. The spherical ball is put for the target objects to arrange.

Fig. 7 is an optimal program for RFID tag arrangement to the floor and attachment to the object. During the navigation, HMR recognizes RFID tags on the floor and objects, and uses them to correct its navigational error as well as for object detection. HMR's localization information generated by self-navigation controller is fed into trajectory controller, so that it refigures out an optimal path to the destination in real-time, and continues on guiding HMR through the new path. HMR paths are normally allocated near and along the wall, in order to better avoid a possible collision with a human. Besides the use of RFID, HMR uses the vision sensor for measuring objects and obstacles, so that the collision avoidance feature and the more agile discrimination of the target object of HMR is effectively implemented. In the region where the recognition of RFID tags is not performed, HMR uses Dead-Reckoning method in navigation. Once a tag is recognized, we could see HMR readjusting its own path and posture for the continuing navigation. In this experiment, we could successfully navigate the HMR to the destination.

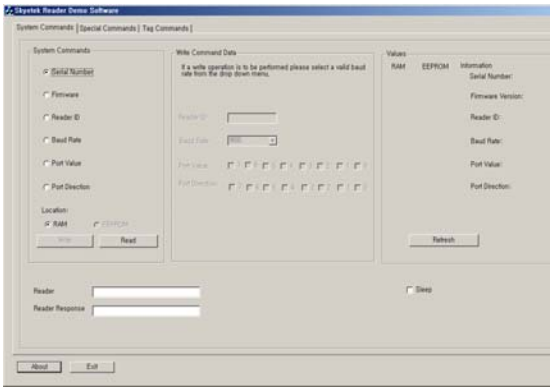

Fig. 7 RFID Tag Arrangement and Attachment

Fig. 8 shows the working results of HMR designed in this paper. HMR is explained on the computer because it has some problems on the mechanical fabrication of real HMR system. We can see the process to arrange an target object in the living room. We can know through the figure that both arrangement and navigation are perfectly performed.

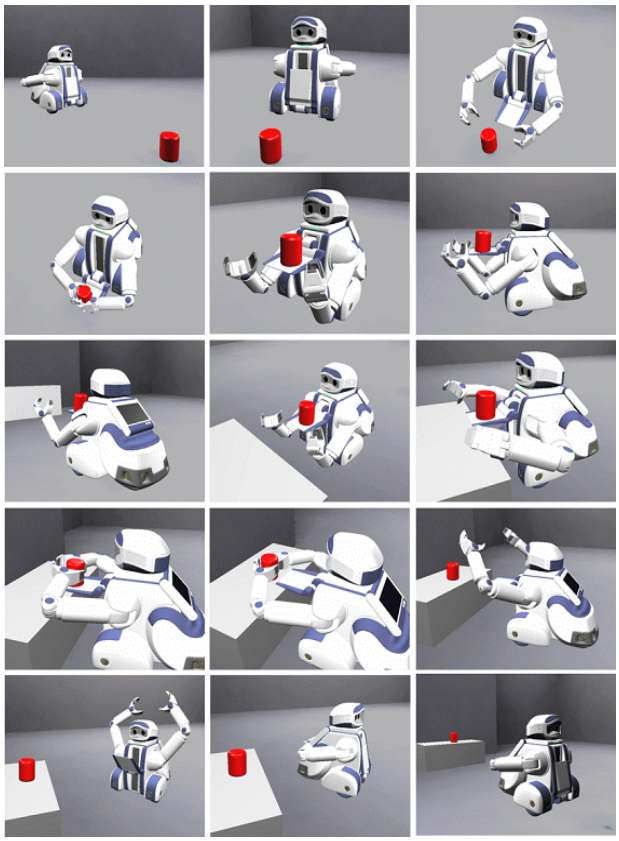

Fig. 8 Working Results of HMR Designed in This Paper

5. CONCLUSION

We proposed a design method and technological algorithm of new automatic machine to solve the problem of mess-cleanup in house. A Home Mess-Cleanup Robot(HMR), which has a practical function of the automatic mess-cleanup, was developed in this paper. It was an agile robot which had functions of stable automatic navigation, noble manipulation system for mess-cleanup.

Then, it should design an intelligent system so that the mess cleaning task can be autonomously performed in a wide variety of situations and environments. With the accurate positional information acquired from self-localization controller, trajectory controller refines HMR's movement to achieve better navigation. For the implementation of self-localization controller, we used RFID technology whose impact in USN application area is rapidly increasing. Not like other conventional sensors, RFID readers do not suffer the line-of-sight problem. It can trivially provide ID information of the sensed objects as well, so that we could better implement autonomous mess-cleanup with RFID. Finally, the good performance of the designed HMR of this paper was confirmed through the experimental results of the mess clean-up and arrangement.

ACKNOWLEDGMENTS

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