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Autonomous Re-alignment of Multiple Table Robots

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Abstract— **This paper reports an experimental system of autonomous omni directional mobile tables and their automatic rearrangement. This system 1. detects the position of meeting tables using a camera on ceiling, 2. makes a route from the detected position by a motion planning and 3. arranges the table robots to the desired positions.**

We developed 4 table robots as multiple omni-directional mobile robots and constructed a position detecting system using LEDs (Light Emitting Diode) attached on the tables. A camera is fixed on the ceiling. We also developed a motion planning algorithm for the robots. Consequently, the table robots can move from an arbitrary arrangement to an arbitrary arrangement. The effectiveness of the proposed algorithm was confirmed.

I. Introduction

In these days, at conference rooms or event sites, people arrange tables to desired positions suitable for the event. If this work could be performed autonomously, it would cut down the man power and time needed. Furthermore, if it is linked to the Internet reservation system of the conference room, it would be able to arrange the tables to an arbitrary configuration by the desired time.

For the reasons depicted above, an "autonomous alignment table system" was experimentally developed. In this system, four meeting tables re-arrange themselves automatically[1]. We provided table robots with omni-directional locomotion mechanism for this experimental system. Their positions are detected by a camera fixed on the ceiling and odometry using the wheel encoders from the initial positions. Goal positions are provided by a GUI interface to input goal positions on a computer. Motion planning from detected initial poses to given goal poses are first simulated on the computer, and then given to the actual table robots to follow.

This paper describes a construction of the entire system, how to detect the position of the tables using the camera fixed on the ceiling and the overview of motion planning algorithm.

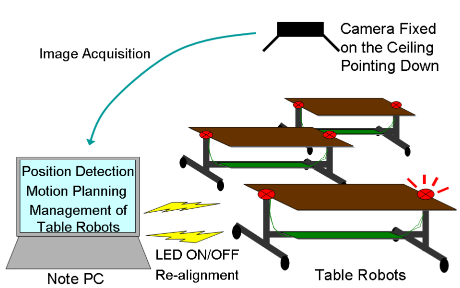

Fig. 1. System Constitution

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II. Outline of the System

Fig.1 and Fig.2. show the system constitution and diagram. The system consists of three elements: 1. table robots, 2. a note PC and 3. a camera fixed on the ceiling. The note PC has a GUI software to input destination of robots, receives images from the camera, process the image to identify the positions of the robots and do the motion planning. The table robots move according to the motion commands issued by the note PC using wireless communications. For table position detection, LEDs are attached at the both end points of a table (Fig. 3.). The LEDs are detected by the camera on the ceiling (Fig. 2.) and the position of each table robots is computed after image processing. Wireless communications Best Technology Co. ZIG100B are used between note PC and each robot.

III. Table Robots

A. Mobile Mechanism

The mobile mechanism of each robot consists of four omni wheels. Omni-directional motion can be achieved by the omni wheels at the four corners of a table. The two omni wheels, two motors and encoders forms a unit which will be attached to and detached from the one side of the table easily (Fig. 3.).

B. Control

Each table robot has a controller CPU which controls all the motors with PI velocity control. The CPU also accumulates the number of revolutions of all the wheels and estimates the position of the robot. The reference velocity which is sent from the note PC is received by the CPU.

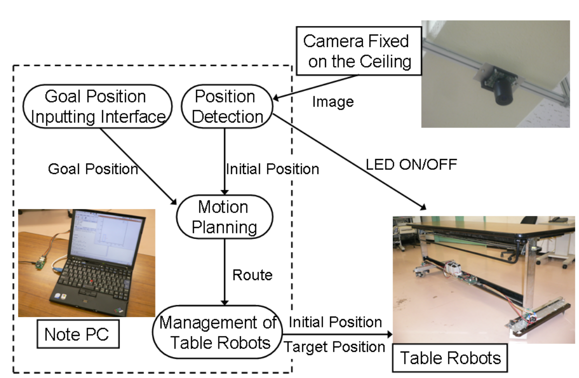

Fig. 2. System Diagram

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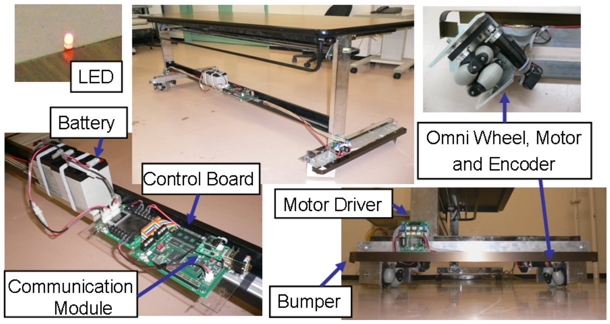

Fig. 3. Table robot

C. Electrical Circuit

The necessary circuits are mounted on the table robot. They consists of a power supply, a control CPU board, and motor drivers. The power supply 24V is used for motors and 5V for the control CPU board system. Renesas Technology SH2/7045 is used for a control CPU. ST Microelectronics L6203 is used for a motor driving H-bridge.

IV. Position Detection using a Camera Fixed on the Ceiling

A. System and Image Acquisition

A monocular camera placed on the ceiling pointing downwards is used to identify the position of the table robots. A Point Grey Research DR2-13S2C-CS camera is used with Fujinon YV2.2x1.4A-2 lens. Two LEDs attached at each endpoint of a table robot are wirelessly controlled to switch on and off. Three images are acquired when the all LEDs are off and each LED is on.

B. Image Processing

The position of each LED is identified by subtraction of the image of all LEDs off from the image of one LED on. It is expected that only a blob of little LED remains on the subtracted image. Centroid of the blob in the image is projected onto a plane whose level coincides with the tabletops and the position of each LED is identified. The projection is based on the perspective transform and lens distortion is taken into account.

V. Motion Planning

A. Problem Definition

We assume the following items are the conditions for motion planning to compute a path for each of the robots:

1) The size of a robot is comparably wide to the given environment. (room size 6mx6m, size of a robot is 183cmx60cm)
2) Motion characteristics of the real table robot must be taken into account for the motion planning. The movement of the robot is restricted by a real robot.
3) The path must be computed within a reasonable time (a second).
4) We consider a static environment where only the robots move and no chairs in the environment.
5) There are no constrains for the initial and goal position of the table robots.
6) The robots have omnidirectional mechanisms.

The major constraints for the motion planner are 1), 2) and 3). On the other hand, conditions 4), 5) and 6) do not put strict constraints for the planner. The motion planning for this issue must deal with multiple robots, however the robots will not have cooperation to achieve a unique task such as to carry a large box. Each robot independently moves from initial to goal position. The motion planner is required to generate paths without any collisions of the robot each other.

B. Algorithm of Motion Planning

The path planner runs in the PC on the ground. From the problem assumptions that are stated on section V.A., we built such a heuristic motion planning algorithm that randomly constructs multiple paths for each robot to arrive at the goal without any collisions [2]. Then the set of paths with the shortest total distance is chosen. In the proposed algorithm a path (a set of waypoints) for each robot to follow is constructed and distributed wirelessly. After receiving the waypoints, the robots follow the path until they arrive their goal.

VI. Achieving Table Re-Alignment

Several tests to check the overall performance of the system are experimented. Robot pose detection is done with the camera, then a path is given to each robot by the motion planner and finally the tables follow the given path. We tested the system by setting up multiple start and goal positions of the robots; in the end, the robots could arrive to the goal position without any collision. Actually we did not find a position configuration that the robots could not achieve.

VII. Conclusions and Future Works

We have developed an autonomous re-alignment robot table system that can save man labor and time effort cost in meeting or hotel rooms. The system is developed, first identifies the position of each of the four table robots using a camera fixed on the ceiling, then plans a path to be followed by each robot and finally each of the robots followed the path to the determined goal. Several experiments using different start and goal configurations proved that the proposed system can reliably perform the self re-alignment task.

As future works, we plan to perform an evaluation of each part of the system and improve the hardware such as automatic chargers or docking mechanism with chair. It will be needed to more evolutions for practical use.

References

[1] K. Ishisaka, E. Takeuchi and T. Tsubouchi, *Autonomous table rearrangement system using omni directional mobile desk*, Proceedings of the 2007 JSME Conference on Robotics and Mechatronics, Japan, 2007, 1A1-N06, (in Japanese).
[2] Y. Sawada and T. Tsubouchi, *Motion Planning for Autonomous Omnidirectional Desk Robots*, The 27th Annual Conference on the Robotics Society of Japan, 2009, 1Q1-01, (in Japanese).