Pebbles: An Interactive Configuration Tool for Indoor Robot Navigation

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ABSTRACT
This study presents an interactive configuration tool that assists non-expert users to design specific navigation route for mobile robot in an indoor environment. The user places small active markers, called pebbles, on the floor along the desired route in order to guide the robot to the destination. The active markers establish a navigation network by communicating each other with IR beacon and the robot follows the markers to reach the designated goal. During the installation, a user can get effective feedback from LED indicators and voice prompts, so that the user can immediately understand if the navigation route is appropriately configured as expected. With this tool a novice user may easily customize a mobile robot for various indoor tasks.

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INTRODUCTION
Devices with autonomous mobility (robots) can be used for various interesting applications in home or office environments. However, it is difficult to teach a mobile robot to go to a specific target location. A number of methods are proposed to solve this problem, such as tangible remote control [1], passive markers [2] and paper tags [3]. However, these pre-defined solutions limit users' reconfiguration and customization in robot navigation applications. Therefore this study addresses the problem of how to assist non-expert users easily and quickly design a navigation route for a mobile robot.

Our system consists of small active markers (called pebbles), a mobile robot, and a set of user interfaces. In the configuration, the user places pebbles along the desired route according to a specific task. The pebbles provide visual LED feedback about the current connection to the user to assist efficient installation. The system also provides voice feedback to users so that they can easily understand if the configuration is appropriately performed as expected. After configuration, the user specifies the ID of the target pebble to send the robot to the specified position (Fig. 1). The user can also call the robot at a distant location by pressing a button on a nearby pebble.

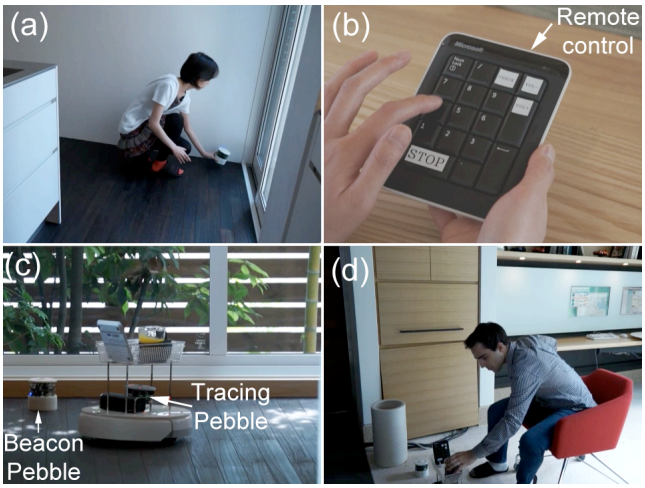

Figure 1: Pebbles: (a) The user places the pebbles on the floor. Each pebble has a unique ID and can communicate with the adjacent pebbles. (b) The user sends the robot to a destination by pressing a labeled button. (c) The robot is navigated by beacon pebbles. (d) The robot arrives at the goal.

IMPLEMENTATION
We have implemented two types of pebbles: beacon and tracing pebbles. Beacon pebbles are small cylindrical devices that fit in a user's palm so that they can be easily picked up and placed at a specific place according to the user, to create a navigation network for the robot. The tracing pebble has a similar design as beacon pebbles, but it is designed to be mounted on the robot and locate other beacon pebbles, so that it can guide the robot to a specific destination.

Beacon Pebble
The beacon pebble is a compact, self-contained device, which is capable of communicating with other beacon pebbles. Using a certain communication protocol and algorithm beacon pebbles construct an ad-hoc network to navigate a robot. Each beacon pebble consists of a microcontroller unit, an IR communication unit and a battery set. All

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components are packed in a φ10cm × 10cm plastic cylinder case. Each pebble has a unique ID to be distinguished in the network. A button labeled with its own ID sits on the top of the case for user input.

The IR communication unit has eight IR transceiver modules; each one contains a red LED indicator, an IR receiver, and three IR signal transmitters. The modules are placed 45◦ apart from each other so that all eight modules obtain good 360◦ coverage. We use encoded IR signals for data communications between each pebble. The signal is modulated with a 38 kHz carrier.

Beacon pebbles are capable of broadcasting and receiving data to and from the network. In addition, every beacon pebble is also able to relay data from one pebble to others. This feature enables the construction of an ad-hoc network.

Tracing Pebble

The tracing pebble has a similar hardware design to beacon pebbles. A big difference is that a tracing pebble only receives data from the network. It neither broadcasts nor relays any data on its own. The tracing pebble sits on the top of the robot. It collects navigation information from beacon pebbles and sends it to the robot. With a specifically designed insulator, each IR receiver of the tracing pebble detects signals within a narrow and directional angle. The tracing pebble has a good proximity and direction estimation ability so that the robot can be navigated with a high accuracy.

INTERACTION

Pebbles work as a tangible user interface for an end user to design a specific navigation route for a mobile robot in an indoor environment. The user first places beacon pebbles on the floor connecting the path according to the desired navigation routes. They work as active markers and communicate with each other so that they can build a map of the environment. Each beacon pebble is associated with a unique ID so that it can be placed at an arbitrary place to label the location with its own ID. The user then sends the robot with a tracing pebble mounted on it to a labeled location in the map. The tracing pebble receives the signals from beacon pebbles and guides the robot to the destination. The system provides visual and voice feedbacks during configuration and navigation procedures.

Interactive Configuration

In the configuration, the user places the beacon pebbles as landmarks. A connection between adjacent pebbles is established when the distance between the two is less than a predefined limit (five meters in our current prototype) and when there is no obstacle between them. Such a deployment automatically generates a spatial representation of the environment.

The system provides effective feedback to assist users to appropriately configure a navigation task. During the pebbles deployment, users can confirm the establishment of a connection by seeing eight LEDs radially placed on a pebble. When transmitting and receiving IR signals, the indicator LEDs of corresponding channels synchronously blink to indicate adjacent relations. The user can see if a pebble is visible to its neighbor pebbles. In this way, the user can know if two pebbles are placed too far apart or some obstacles block the path directly between them, and immediately correct the problem.

Besides the visual feedback, the system also provides voice prompts for better assistance. While LEDs indicate pairwise connection status, the voice prompts report the connectivity of the entire network. With such interactive assistance, a user can avoid installation failures for a customized navigation application. The user press the “check” key on the remote, and the system reports which landmarks are connected to the network with auditory feedback such as “I can locate number one, number three, and number five.”

Perform a Customized Task

Once the configuration is finished, the user can immediately perform a customized task. The user sends a nearby robot to a desired distant destination by pressing the key on the remote control associated with the ID of the pebble located at the destination. The user can also call a distant pebble to the user’s current location by pressing the button on the nearby pebble. The robot immediately examines whether the specified destination is reachable or not and provides voice feedback to the user. During the approach to the target, the robot continuously reports its status using voice prompts.

The ability of customizing a navigation task implies several potential applications using pebbles. A user is able to carry a pebble and call a service robot at anytime. It is also possible to apply pebbles for dynamic targets. For instance, when a user wants to send a robot to another user, the sending user can simply press the number associated with the pebble carried by the receiving user.

CONCLUSION AND FUTURE WORKS

We presented an interactive configuration tool for non-expert users to easily create a customized navigation network for indoor robots. An initial prototype system consisting of a number of tangible landmarks and a set of user interfaces were developed. In the future, we would like to explore the usability of our system in designing customized navigation applications for non-expert users.

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