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Indoor Navigation for Mobile Robot by Using Environment-Embedded Local Information Management Device and Optical Pointer

Tsuyoshi Suzuki[1], Taiki Uehara[2], Kuniaki Kawabata[3], Daisuke Kurabayashi[4], Igor E.Paromtchik[3], and Hajime Asama[3]

[1] Department of Information and Communication Engineering, Tokyo Denki University, 2-2, Kanda-Nishiki-Cho, Chiyoda-ku, Tokyo, 101-8457, JAPAN
tszk@ieee.org

[2] EPSON KOWA Corp., Ueda, Nagano, JAPAN

[3] The Institute of Physical and Chemical Research (RIKEN), Wako, Saitama, JAPAN

[4] Tokyo Institute of Technology, Meguro, Tokyo, JAPAN

Abstract. The paper discusses a new hybrid navigation strategy for mobile robots operating in indoor environment using the Information Assistant (IA) system and the Optical Pointer (OP). For intelligent navigation, the robots need a static and global information describing a topological map such as positional relation from any starting position to any goal position for making a path plan as well as dynamic and local information including local map, obstacles, traffic information for navigation control. We propose a method for managing the information. The robot has only rough path information to the goal, and the IAs, which are small communication devices installed in the environment, manage real environment information, locally. The OP is used for guidance of a robot in the junctions such as crossing, which communicates with mobile robots through IA and indicates their target positions by means of a light projection from a laser pointer onto the ground. The mobile robot allows it and run after the laser light beacon and reaches the destination. The robot can navigate to the goal efficiently by using these systems.

1 Introduction

In recent years, an application range of a robot is spreading to general indoor environment with many indefinite elements from limited condition environment such like in a factory where the industrial robots are used. In such a background, it is important subject for a mobile robot research to be navigated a robot to a goal correctly. Although, there are many research for robot navigation[e.g.1], the robot is beforehand given a detailed map in almost all researches. In such methods, however, it is difficult to cope flexibly according to problems which occur in the situation of changing every moment. Management of the information according to every change of the environment is also difficult.

The paper discusses a new navigation method for multiple mobile robots operating in indoor environment. In order to realize a flexible navigation, a management method of environment information is considered. For intelligent navigation, the robots need two types of environment information. That is, they are static and global information

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describing a topological map[2] such as positional relation from any starting position to any goal position for making a path plan and local information including local map, obstacles, traffic information for dynamic navigation control. The robot has only simple path information to the goal and the Information Assistant (IA), which is small communication devices installed in the environment, manage real environment information, locally. In addition, the Optical Pointer (OP) is used for guidance of a robot in the junctions such as crossing, which communicates with mobile robots through IA and indicates their target positions by means of a light projection from a laser pointer onto the ground. The mobile robot allows it and run after the laser light beacon and reaches the destination. The robot can navigate to the goal efficiently by using these systems. There is research which is the robot itself judging all information in the environment for navigation by using improved topological map[3]. However, it is difficult to share the information with other robots. By using IA and OP, more flexible navigation and information management are expected. Section 2 presents the proposed management method of environment information. A navigation system by using the method is developed in a section 3. Section 4 illustrates experimental results. The conclusions are given in section 5.

2 Map Information Management for Navigation

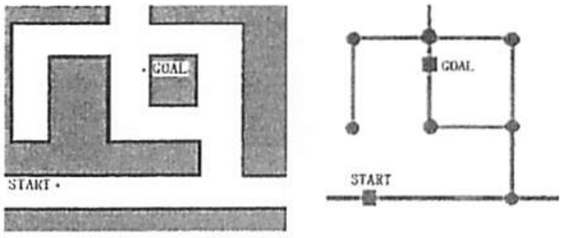
In this research, an indoor environment enclosed with the wall which consists of a passage and a junction is assumed. For flexible robot navigation, we classify two types of environment information. One is global information which is used path planning roughly. The other is local information which is detailed information depending on the place. The local information is used for accurate navigation control with in a path. The management methods of these information are described in this section.

2.1 Global Map Expression for Path Planning

In order to plan the path to the goal, map information that shows the position relation of a present location, goal and passing point roughly are needed. We decided that such global information is given as a topological map. For example, topological map of the environment shown in Fig. 1 (a) is represented as Fig. 1 (b) by using graph expression. In this map, accuracy of the environment information such as position distance etc. is disregarded. Only the simplified position relation of the environment is expressed with this map. A robot can plan a rough path for navigation by using graph search method on the basis of this global map information given beforehand.

2.2 Local Information for Actual Navigation

Although a rough path is planned by the global environmental map, it is necessary for the robot to determine the trajectory to which a robot actually runs in the path. For example, the robot can easily runs along wall in a passage. However, the robot



(a)Example of indoor environment (b)Topological map

Fig. 1. Global map expression

cannot run easily on a junction. Since the form of junction is not uniform, it cannot give the trajectory beforehand. Moreover, it is needed a traffic control because passing of other robots and man's crowd into the junction. Furthermore, since a wall does not exist in a crossing, the run position control accompanied by self-position identification of a robot is difficult. For smooth navigation in a junction, the robot needs to know the state of information of junction which will run. However, such information depends on the each place and state. Then, we define such information as local information and make the environment itself to manage it. The robot can plan the suitable run trajectory in the local place by acquiring local information from the environment.

3 Local Information Management for Navigation

3.1 Information Assistant and Optical Pointer

In this research, the local information is managed a Information Assistant (IA) which is radio accessing device. IA is the small device with functions, such as managing local information, communication with a robot, and control of connected another device such as sensor. IAs are embedded the junction or other place with local information. By using the IA Reader/Writer, the robot can read the information from IA, and also write the information which the robot has to IA. Furthermore, communication is also possible by other robots reading the information which the robot wrote in IA.
IA gives a information according to a demand of a robot for trajectory planning. However, it is difficult for the robot to run the trajectory correctly only on the basis of this information. For example, Figure 2 shows a arrival point that the robot run a junction by using it's odometer. This shows that arrival points are not fixed. The following things can be considered as this cause.

1. Since the robot detects IA by the electric wave, variation arises at time to detect. Therefore, start position which the robot moves in junction is not fixed.

2. Detection error of the angle between wall and robot occurs when a robot starts revolution to the trajectory direction.
3. The run error at the time of crossing occurs.

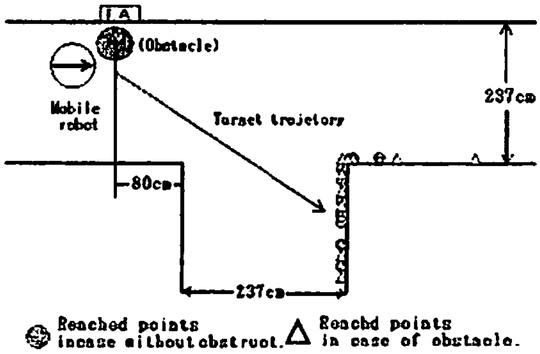


Fig. 2. Experiment of mobile robot operation using IA

In addition, the error is larger when an obstacle exists near a start point. Then, we use a Optical Pointer (OP)[4]. OP has pan-tilte mechanism, and can points the sub-goal of the robot by a laser spot. OP is controlled by IA. The robot can detect laser spot by using CCD camera and image processing, then move to near by laser spot. OP can give a trajectory to the robot by moving laser spot. Figure 3 shows a concept of this optical guidance system.

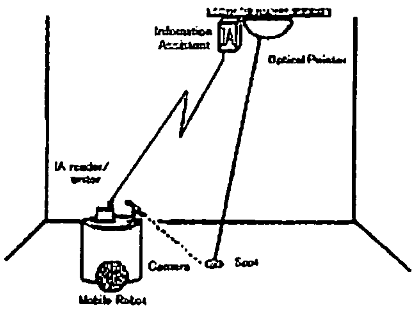


Fig. 3. Concept of the optical guidance system

3.2 Navigation Algorithm of the System

The navigation algorithm by using the above method is shown as follows:

1. The robot is given the topological map of the whole environment and a present location.

2. The robot is given a command of goal information through wireless LAN from an operator.
3. On basis of start and goal information, the robot plans a rough path with referring a topological map by using graph search method.
4. The robot starts to move.
5. The robot runs along wall in a passage direction of the goal according to a path planning. The robot can also detect a obstacle by infrared sensor, and avoid it.
6. When the robot arrives at a junction, it will detect the response from IA. Then, the robot communicates with IA and requests the guidance in the junction. Figure 4 shows a communication process between the robot and the IA.
7. The IA receives a start and goal information from the robot, and give a trajectory information to the robot with referring a local information.
8. The IA gives a laser spot as a target point for the robot movement by using OP on basis of the trajectory.
9. The robot detects a laser spot from OP which controlled by IA, then moves to the spot. IA guides a robot with moving a laser spot along the trajectory in a junction.
10. When the robot arrives a another passage, the robot sends a arrival message to the IA. Then, the guidance by IA is finished.
11. The robot starts an along wall run again.
12. When the robot puts in another junction, the optical guidance is executed. If the robot detect a goal information form IA, the task is finished.

In addition, in the case of many robot move into the junction simultaneously, the robot which communicated first with IA receives guidance service. Other robots receives a busy signal from IA, then wait on current position until service becomes possible. Therefore, navigation is possible even if two or more robots exist in the environment.

4 Navigation System

In order to realize a proposed navigation, the prototype system is developed. This section describes a details of the system.

4.1 Omni-Directional Mobile Robot

The omni-directional mobile robot ZEN has been already developed for realizing flexible action[5](Fig. 5 (a)). The control system is mounted on the robot. Batteries are also mounted on the robot for electrical devices and actuators. The robot can behave autonomously and independently.
The robot has an infrared sensor system called LOCISS (Locally Communicable Infrared Sensory System)[6] shown in Fig.5 (b). The robot can detect a wall and run along wall by using LOCISS, and can also detect a obstacle and avoid it.

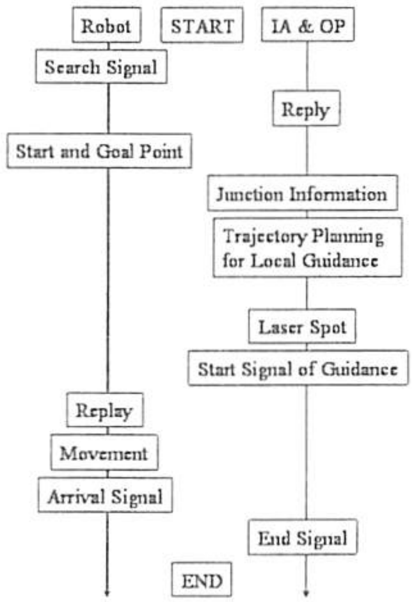
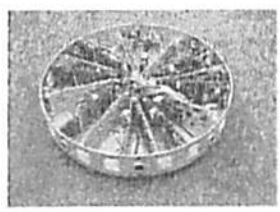


Fig. 4. Communication between robot and IA



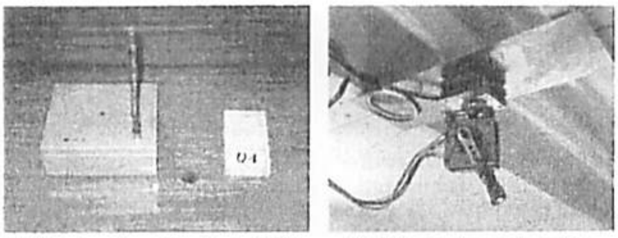
(b) LOCISS

(a) Omni-directional mobile robot ZEN

Fig. 5. Omni-directional mobile robot

4.2 Information Assistant and Optical Pointer

Figure 6 (a) shows a Intelligent Data Carrier (IDC)[7] and IDC Reader/Writer. IDC is a small device which consists of radio communications part, CPU, memory and battery. The robot can communicate with IDC through IDC Reader/Writer. In this research, we used this IDC ver.4 as IA, and installed in the environment. For local navigation in a junction, OP (Optical Pointer) was developed. Figure 6 (b) shows a OP which is installed in the ceiling. OP consists of two stepping motors for pan-tilte motion, two motor driver for driving stepping mōtor and a laser pointer. OP is connected to IA by the cable. IA controls the actuators and laser pointer of OP. It is enabled to give a laser spot flexibly on the floor surface.



(a) Right : Intelligent Data Carrier(IDC)
Left : Reader/Writer

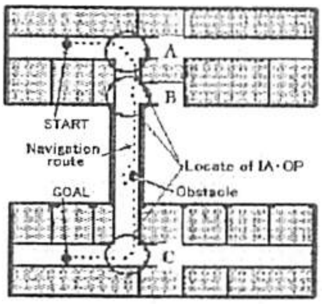
(b) OP mechanism on the ceiling

Fig. 6. IA and OP

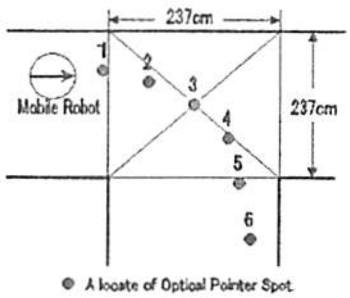
5 Experiments

The proposed system was installed to an indoor environment where was the second floor of our building in RIKEN. Figure 7 (a) shows the floor map of experimental environment. The task of the robot is movement from its present location to a goal which is given by the human. IA and OP are installed in all junction of the floor. They have information about own position and junction state. The circles A, B and C of Fig. 7 (a) show junctions where the IA-OP system is installed and also show communication and local navigation range of each IA-OP system.

Experimental result is also shown in Fig. 7. The robot had information of current position as START, and was given a goal such as shown in Fig. 7 (a). Then, the robot planed a rough path such like START - A - B - C - GOAL with referring a topological map by using graph search method. After that, the robot run along the wall based on a rough path by using LOCISS, and can also avoid a obstacle. When the robot approached to a junction, the robot detected and communicated with IA. The IA projected a laser spot onto a floor surface as a target point for the robot movement by using OP. The IA provided a trajectory to the robot by moving a laser spot. Figure 7 (b) shows a trajectory which is given a laser spot movement in junction A. Likewise, the robot could reach the goal by using both of an along wall run based on rough path planning by using topological map and the local navigation in junction B and C. The dotted line in Figure 7 (a) shows the actual trajectory of the robot. Figure 8 shows a situation of local navigation in junction.



(a) Map of the experimental environment and a trajectory of the robot



(b) Location of OP spot position in Junction A

Fig. 7. Experimental Result

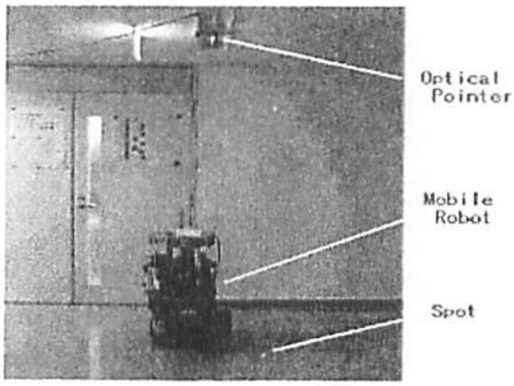


Fig. 8. Robot navigation experiment using IA and OP

6 Conclusion

The new navigation strategy for mobile robots operating in indoor environment is proposed. The robots need a static and global information describing a topological map such as positional relation from any starting position to any goal position for making a rough path plan as well as dynamic and local information including local map, obstacles, traffic information for accurate navigation control. For intelligent navigation in indoor environment, we classified the information into two types such as global information and local information and proposed the method for managing each type using the IA system and the OP. The navigation algorithm by using the system was presented. The experimental example of navigation by using this system is shown. The robot could navigate to the goal efficiently by using the systems.

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