

Design and Implementation of a Service Robot System based on Ubiquitous Sensor Networks

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Abstract: - Design and implementation of an autonomous service robot system based on ubiquitous sensor networks(USN) is proposed. Autonomous acquisition of the position information of a service robot is obtained through the integration of a given global map, USN motes and distance sensors without using cameras. Navigation of the service robot in a building is based on the given building map and the acquired position information. The functions that are relevant to robot movement such as path control, obstacle detection and avoidance are managed by a server notebook PC on the robot platform. According to a given building map, a proper set of locations for USN motes are determined. When a service robot passes by a mote, a set of an LED and a photo-transistor on the service robot and motes detects each other. When a mote detects a specified signal, then it reports to its server immediately. When a service robot detects a mote and then it receives a report from a mote in a short interval of time such as 100 msec, then a server makes decision that the service robot is in front of a mote which reported just before. Since the locations of motes are known, the location of a service robot is determined by the detection sensors and USN motes. Between the USN motes, position data of a service robot is obtained by the distance sensors and encoders that are mounted on the robot platform. Autonomous errand services from any location to given places by user's commands in a large building are possible through experiments by a Pioneer2 and ZigbeX system.

Key-Words: - Service Robot, Ubiquitous Sensor Network, Autonomous Positioning

1 Introduction

In this work, we propose a general framework to get location information of a service robot based on emerging ubiquitous sensor networks without relying on conventional methods using cameras. Then we show the results of an exemplary implementation of an autonomous errand service robot system from any location to given places by user's commands in a large building through experiments by a Pioneer2 and ZigbeX system. Ubiquitous computing provides useful services to its users in their real life regardless of their location via integration of sensors, computers and their networks as described in [1]. Ideally, computing devices, electronic appliances including robots, and I/O devices such as display, sensors and actuators are networked to

each other so that many kinds of applications and services are possible anytime at any place in a ubiquitous space. Mobility of robots can enhance the quality of ubiquitous computing services. Also, the horizon of ubiquitous computing applications can be broadened by the convergence of dynamics with ubiquity.

The traditional methods based on using cameras and image processing techniques are common for robot navigation problems. However, due to the advent of ubiquitous sensor network technologies, navigation of service robots is possible through the application of USN instead of using cameras and image processing techniques. Autonomous acquisition of the position information of a service robot can be obtained by the

integration of a given building map, locations of USN motes and outputs of distance sensors without using cameras. Navigation of the service robot in a building is based on the given building map and the acquired position information. According to a given building map, a proper set of locations for USN motes are determined so that service robots can navigate autonomously. When a service robot passes by a mote, each set of an LED and a photo-transistor on the service robot and motes detects each other. When a mote detects a specified signal from a robot, it reports to its server immediately. When a service robot detects a mote and then it receives a report from a mote in a short interval of time such as 100 msec, a server makes decision that the service robot is in front of a mote which reported just before. Since the locations of motes are known, the location of a service robot is determined to be that of the reporting mote by the conditions of detection sensors on the robot and the report of USN motes.

Between the USN motes, the location of a service robot is obtained by the distance sensors, e-compass and wheel encoders that are mounted on the robot platform. The functions that are relevant to robot movement such as path control, obstacle detection and avoidance are managed by a server notebook PC on the robot platform using input signals from sonar sensors around the robot body.

2 Service Robot System based on USN

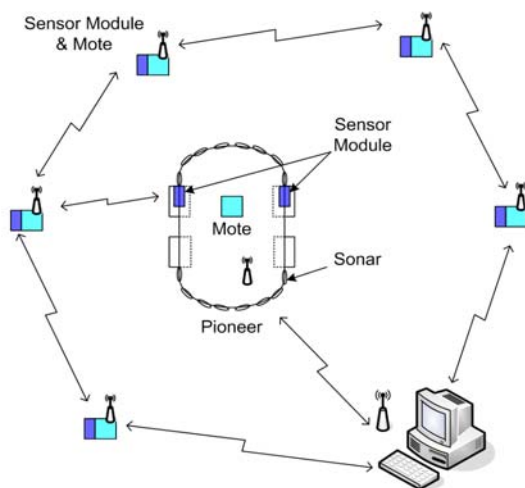


Fig. 1. Deployment of USN motes

There are various kinds of service robots can perform for people. Throughout the applications, the ability to locate

the robots is important. Therefore, many kinds of localization methods have been developed so that required robot performance can be achieved based on the acquired positional data. The traditional methods based on using cameras and image processing techniques are common for robot navigation problems.

There are practical restrictions to use images in ubiquitous sensor networks due to low traffic rates, large amount of information, low capacity of microprocessors and power consumption. Therefore, a new method is adopted that does not need camera images to get robot's position data.

The adopted method utilizes the functions of ubiquitous sensor networks that are assumed to be deployed. A simple card as shown in Fig. 2 that contains a set of an LED and a photo-transistor for photo detection is added on each mote and the service robot.

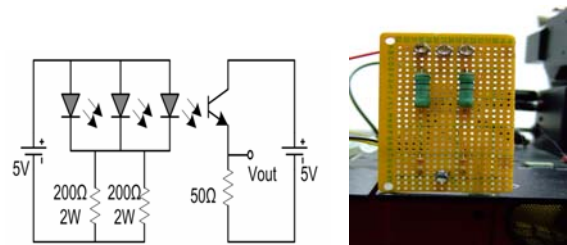


Fig. 2. Photo-sensor module

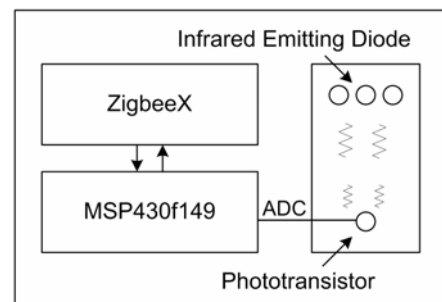


Fig. 3. A pair of USN mote and sensor module

When a service robot passes by a mote in a detectable range, the photo-transistor on the service robot detects the LED on the mote, and the photo-transistor on the mote also detects the LED on the robot. Whenever a mote detects a specified signal from a robot, it immediately reports the detection to its server. When a service robot detects a mote and receives a report from a mote in a short interval of time such as 100 msec, a server makes a decision that the service robot is in front of a mote which reported a detection just before. Though there are many answering motes in the range, there is only one mote that reports the detection of the robot in a short interval of time. When there is a false detection reported from a mote that is not close to the robot, the server does not make the conclusion for the robot's location since there is no detection of a mote by the robot in a short interval of time.

Since the locations of motes are known, the location of a service robot is determined to be that of the reporting mote by the conditions of detection sensors on the robot and the report from one of USN motes.

When a service robot is between the USN motes, the location of the robot is obtained locally. Since the motes are placed at every point where a service robot should pass by indoors, it can be assumed that the maximum distance between any two consecutive motes is not far away. There are distance sensors, e-compass and wheel encoders that are mounted on the robot platform so that the distance and direction of a robot can be measured. When a robot reaches the next mote, the distance and direction values are calibrated based on the known data of the mote.

The functions that are relevant to robot movement such as path control, obstacle detection and avoidance are managed by a server notebook PC on the robot platform using input signals from sonar sensors around the robot body along with the location

3 Errand Service Robot based on USN

Among the various types of services that a wheel-based robot(Fig. 4) can perform, errand service is chosen to demonstrate the effectiveness of using USN motes for localization and robotic service applications. The environment for the service is restricted in a large, eight-stories building with elevators(Fig. 5). The main objective of an autonomous errand service is to carry some small things such as letters, documents, CD/DVDs or whatever that can be put on the top of the

robot from any location to given places by user's commands in a large building.

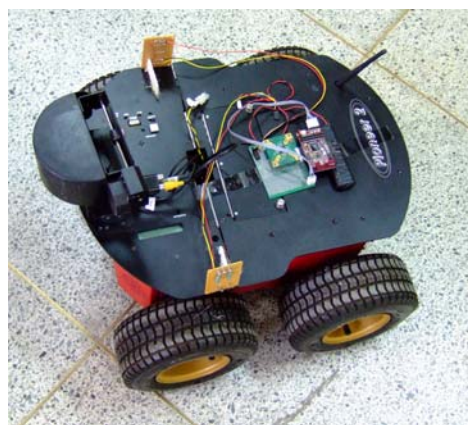


Fig. 4. Errand service robot based on USN

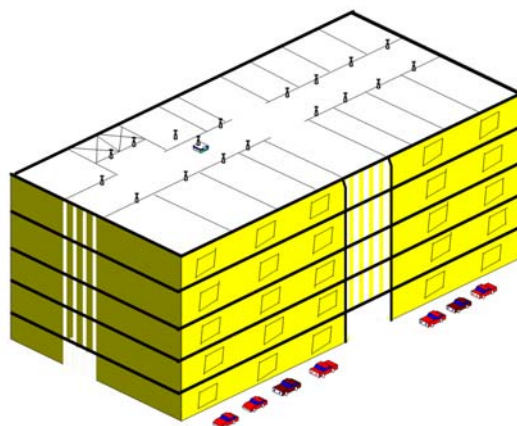


Fig. 5. Environment of an errand service robot

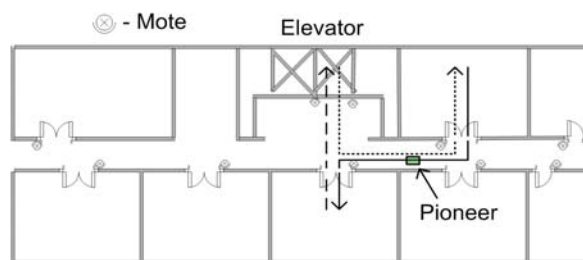


Fig. 6. Detailed environment: part of 6th floor

The steps for an errand service are:

1. Call an errand robot to come to a place specified by a command.
2. The requested errand service is queued.
3. Report the number of requests to be done before.

4. In order of requests, an errand robot comes to the specified place.
5. Put articles on the robot.
6. Give a sub-command to go to a specified place.
7. When an errand robot gets to a destination, terminate the request or allow it go to a specified place by a command.
8. If terminated, go to step 4; if not terminated, go to step 5.

4 Implementation of Service Robots

The overall scheme of requested services consists of the following three actions;

- Move from one place to another place on the same floor.
- Move from one place to get into an elevator.
- Get out of an elevator, and then move to a specified place.

from one place to get into an elevator, and moving to a specified place after getting out of an elevator.

Due to mechanical restrictions, doors open/close, elevator's floor buttons are out of the reach of the service robots. Those required actions are shown on an LCD panel, and the necessary actions are currently done by an assistant.

To accomplish a natural performance that is necessary for an errand service robot, there are several basic actions to be done. They are:

- Identifying a mote to get robot's position data
- Movement to a specified position
- Getting into/out of an elevator
- Obstacle detection
- Obstacle avoidance and path planning
- Waiting and emergency stop
- Communication between motes

The basic situations and required actions to be done by an overall programming are represented in Fig. 7.

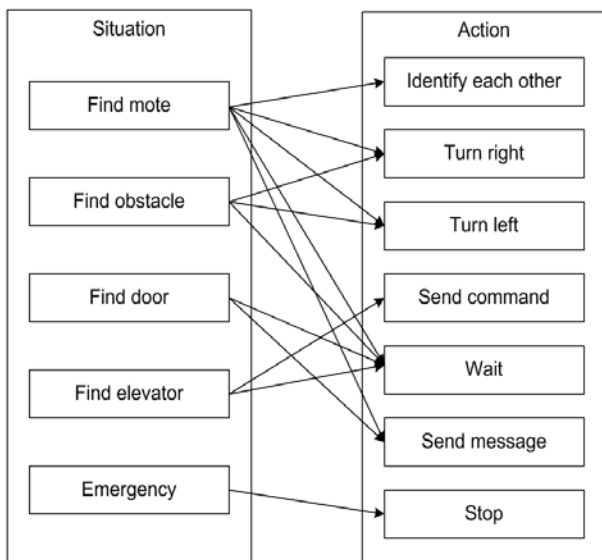


Fig. 7. Overall situations and actions

For example, let a request be;

- 1) going to Room #617 which is on the 6th floor,
- 2) loading articles,
- 3) going to Room #405 which is on the 4th floor,
- 4) loading/unloading articles,
- 5) going to Room #705 which is on the 7th floor,
- 6) unloading articles, and
- 7) termination of a request.

However the request consists of movements, they can be divided into three basic movements; moving from one place to another on the same floor, moving

5 Experiments

The platform of an errand service robot is based on a Pioneer2 robot, and the Zigbex ubiquitous sensor networks(www.hanback.co.kr) are used for the configuration of the experiments.

All important points in a building such as rooms, offices and elevators are designated by motes. Since vision systems such as cameras and image processing are not used for this application, all places of interests are identified by the motes. Through USN communication and photo-sensor detection, any specific mote can be identified. Finding a mote means knowing the place that the mote represents and its position on the building map.

Between the USN motes, robot's position data are calculated by distance sensors, e-compass and wheel encoders that are mounted on the robot platform. Therefore, the distance and direction of a robot can be measured from a starting mote. When a robot reaches the next mote, the distance and direction values are calibrated based on the known data of the next mote. In this experiment, the distance and direction errors are negligible since the consecutive motes are close to each other. While a robot is moving it keeps a certain distance from a wall using sonar sensors as far as there are no obstacles. When an obstacle is found it makes a beeping sound and wait several seconds, then it detours to avoid collision based on sonar sensors around the robot body.

Fig. 8-10 show the results of the basic movement commands, going from one place to another on the same floor, getting into an elevator from one place, and going to one place after getting out of an elevator, respectively.

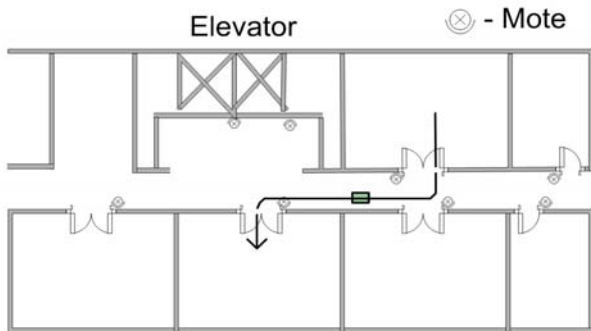


Fig. 8 Movement on the same floor

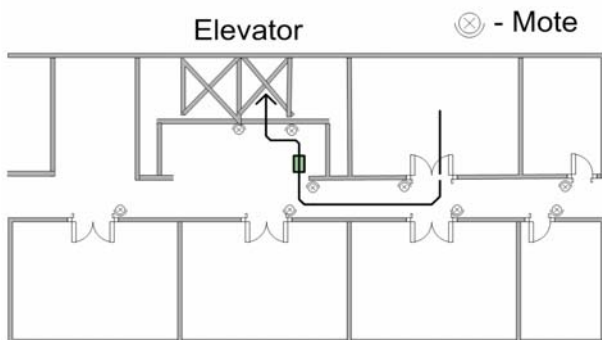


Fig. 9 Getting into an elevator from one place

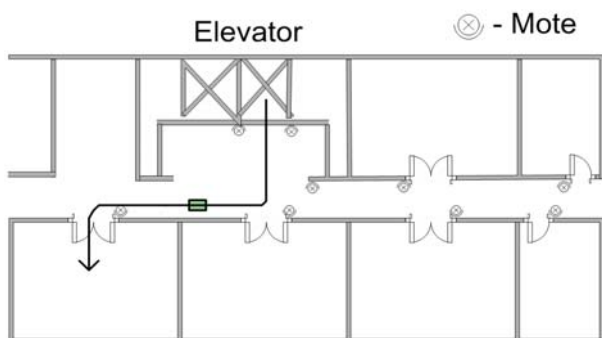


Fig. 10 Getting out of an elevator

The result of an obstacle avoidance when something not expected is found is shown in Fig. 11.

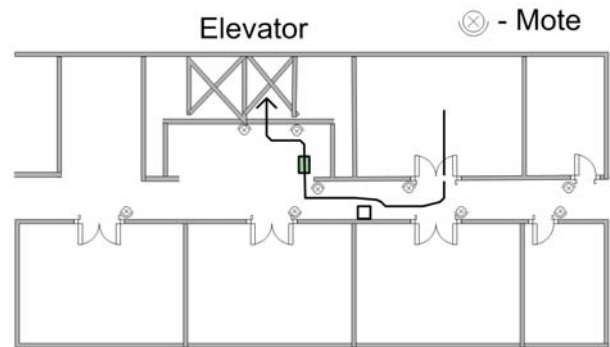


Fig. 11 Collision avoidance during movement

The overall program to accomplish a natural performance that is necessary for an errand service robot is very complicated. It should manage navigation, collision avoidance, path planning, and handling emergency status. However, there is a trade-off between program complexity and the number of deployed motes. The more motes deployed along the paths in a building, the simpler the programming becomes. However, the price of the motes is not negligible until today since USN is an emerging technology. Also, there is a trade-off between program complexity and speed of an errand robot. The slower the speed of a robot, the easier the programming becomes. It might be ideal to have speed of about 3 miles/hr considering indoors. But the speed becomes much slower when the number of obstacles increases.

6 Conclusion

A new method that employs ubiquitous sensor network motes for localization without using cameras or vision systems is proposed for an errand service robot application. The overall design and implementation of an autonomous service robot system based on USN motes are realized to show its plausibility. Autonomous acquisition of the position information of a service robot is obtained through the integration of a given global map, USN motes and distance sensors without using cameras. The functions that are relevant to robot movement such as path control, obstacle detection and avoidance are managed by a server notebook PC on the robot platform.

Between the USN motes, the location of a service robot is obtained by the distance sensors and encoders that are mounted on the robot platform. Autonomous errand services from any location to given places by the user's commands in a large building are shown possible through experiments by a Pioneer2 and

ZigbeX system. The trade-off between program complexity and number of deployed motes is a practical problem to solve in a real implementation.

Acknowledgements

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