Remote Navigation System for Mobile Robot using USN and Image Information

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Abstract

In this paper we use Ubiquitous Sensor Network(USN) and image information to develop remote navigation system for mobile robot. USN with ultrasonic sensors is used to estimate local position of mobile robot. Using this information of position, mobile robot can navigate in certain area autonomously. And USB web-camera is used to obtain real-time images of remote places and monitor it, when mobile robot navigates remotely.

Keywords: *Sensor Network, Mobile Robot, Navigation, Image, Ultrasonic Sensor.*

1. Introduction

These days researches for unmanned autonomous mobile system using Ubiquitous Sensor Network(USN) have been performed. It is called networked robotics which is realized by convergence of wireless communication, sensor and robotics technology. Networked robotics has evolved into a distributed processing system which is achieved by low cost, low power consumption and combining with sensor network. By this, target searching in certain area, searching and chasing of invader, and real-time monitoring can be implemented.

Networked mobile robots combined with USN use information of sensor network to navigate arbitrary path autonomously in certain area, and need estimation and compensation of its position for navigation. There are several methods to estimate position of robot in certain area: 1) use encoder information from wheel of robot, 2) use acceleration or gyro sensor information etc. But these methods cause serious problem when robot navigates long time, because measurement errors by sensors or gliding of robot are accumulated [1, 2]. That is, the position of robot is no longer correct, because of accumulated errors. These days, as alternatives to previous methods, another estimation methods have been proposed using ultrasonic or infrared sensor, RF, RFID, and GPS etc. GPS can't be used indoor environment and has large estimation error. RFID demands large cost by increasing number of tags and causes inexact estimation of position because of receiving multiple information from same tag [3].

In this paper a method of estimation of local position of mobile robot using USN and ultrasonic sensors is proposed and remote navigation system for mobile robot is developed. Sensor network nodes which are installed at certain positions in given area, measure distances from navigating robot through ultrasonic sensors and send these to server computer. To solve a problem of inaccuracy of measurement, we rotate ultrasonic sensors which are attached to

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robot in 360 degrees and can obtain accurate distances. Triangulation is used to estimate local position of mobile robot from measured distances between sensor network nodes and moving robot. Estimated position of robot by ultrasonic sensors is also used to correct estimated position by encoder, and direction of robot. Web-camera attached to robot send real-time images of environment to server computer. We can monitor surroundings and respond emergency situation.

2. Position Estimation and Navigation

2.1. Measurement of Distance using USN and Ultrasonic Sensors

There are various methods to measure distance between two objects : 1) TOA(Time of Arrival) uses arrival time of signal, 2) TDOA(Time Difference of Arrival) uses differences of arrival time of signals, 3) AOA(Angle of Arrival) angle between objects, 4) RSSI(Received Signal Strength) utilizes strength of signal etc.

We use TOA method to measure distances between nodes and moving robot in this paper. TOA measure arrival time of ultrasonic or RF signal from sending node to receiving node, and multiply it by velocity of signal to calculate distance. TOA can calculate distance more exactly, when velocity of signal is low. When it takes time, t(sec) for ultrasonic signal to start from sending node and be received by receiving node, distance between sensor nodes, S is calculated as below:

$$S = v \times t = 340 \times t \, . \qquad (\mathbf{1})$$

where, v is velocity of sound, 340(m/s) at 15 (°C). At equation (1), velocity of sound varies according to air temperature. So it can be adjusted as below:

$$v = 331.5 + 0.6T \, . \qquad (2)$$

We use ZigBee based wireless sensor network package and ultrasonic module to estimate distances between nodes and position of mobile robot. Mote of package is composed of microcontroller, ATmega 128L, wireless communication chip, CC2420, various sensors including temperature, humidity etc, and antenna.

2.2. Estimation of Position by Triangulation

We use Triangulation method to estimate position of robot. By triangulation we calculate position of moving node from distances between moving node and reference nodes of which coordinates of positions are known. If the coordinates of k-th reference node are $\boldsymbol{n}_k = [n_{k1} \ n_{k1}]^T$ and those of moving node $\boldsymbol{x} = [x_1 \ x_2]^T$, distance between reference node k and moving node, d_k is as follows:

$$d_k = \| \boldsymbol{x} - \boldsymbol{n}_k \|. \qquad (3)$$

where, $\| \cdot \|_2$ represents 2-norm. Using more than two pairs of coordinates of reference node, $\boldsymbol{n}_k$ and distance, d_k , coordinates of moving node, $\boldsymbol{x}$ can be solved from eq. (3). In order to obtain position of moving node by Triangulation, we need to measure distances between reference nodes and moving node accurately. Ultrasonic signal has high accuracy for measuring distance indoors, but it has small angle of beam spread. To solve a problem of inaccuracy of measurement, we rotate ultrasonic sensors which are attached to robot in 360 degrees and can obtain accurate distances.

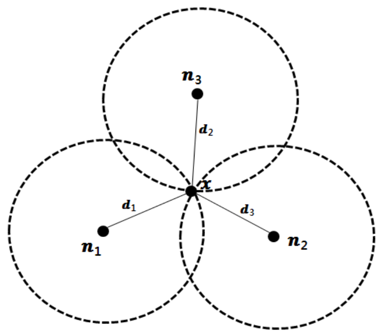

Figure 1. Schematic diagram of Triangulation method

2.3. Navigation Algorithm

Estimated position of robot by ultrasonic sensors is also used to correct estimated position by encoder and direction of robot. Using this information of position and direction, mobile robot can navigate in certain area automatically. At time, t , relation equation of rotation angle of wheel of robot, $\Delta\ \Theta$ (°) and moving distance of robot, $\Delta\ d$(cm) is as follows:

$$\Delta d = \pi \times R \times \Delta\theta/360\ . \tag{4}$$

$$d(t+1) = d(t) + \Delta d\ . \tag{5}$$

$$\theta(t+1) = \theta(t) + \Delta\theta\ . \tag{6}$$

where, R is diameter of wheel of robot.

3. Image Processing of Mobile Robot

To monitor remote areas where mobile robot navigates and implement remote navigation system, real-time images of the places are sent to server computer. JMF(Java Media Framework) and RTP(Real-Time Transfer Protocol) technology is used to process images. JMF is developed by Sun inc., and has a structure and message protocol to send, process and acquire of media. RTP is designed to send media stream, and supports JMF. It solves problems such as network transfer delay which traditional TCP/IP based HTTP and FTP have. And it fits to send multimedia data in real-time. Server computer finds USB web-camera(video device) from all capture devices and generates MediaLocator which indicates resource location of media Data. And it generates Processor to send media stream in data source. Through RTPManager, RTP session is generated, managed and terminated, and media stream which is sent to and received from client is managed.

Receiving media stream using RTPManager in client is similar to sending in server. DataSource received through RTPManager generates Player for media replay. Generated Player registers event. When Player enters, it acquires component to replay media stream from server.

4. Experiment and Results

We make an experiment place to evaluate performance of estimation of position and navigation system of mobile robot using wireless sensor network and ultrasonic sensors. Its magnitude is 5 x 5(m^2) and rectangular coordinates are assigned. Four reference nodes, Node 1, 2, 3 and 4 are installed at each corner, which have coordinates of (0, 0), (5, 0), (5, 5) and (0, 5). Mobile robot starts from position, (2, 0) and moves through assigned path in experiment place.

Figure 2 and 3 show screen images of navigation system for mobile robot by proposed method and encoder only. In figures • represents estimated position of mobile robot by encoder, ○ real navigating path and circle with shade estimated position of mobile robot by proposed method.

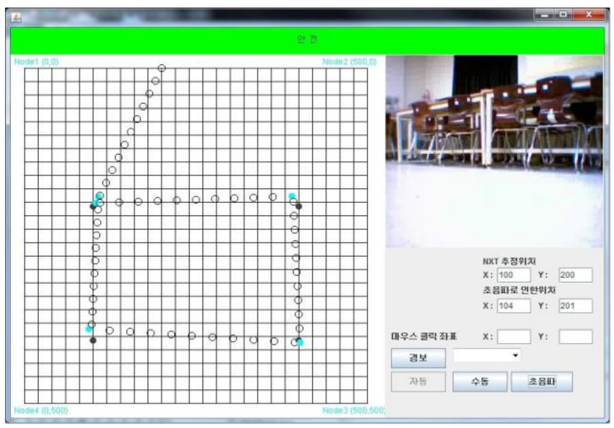

Figure 2. Screen image of navigation system by proposed method

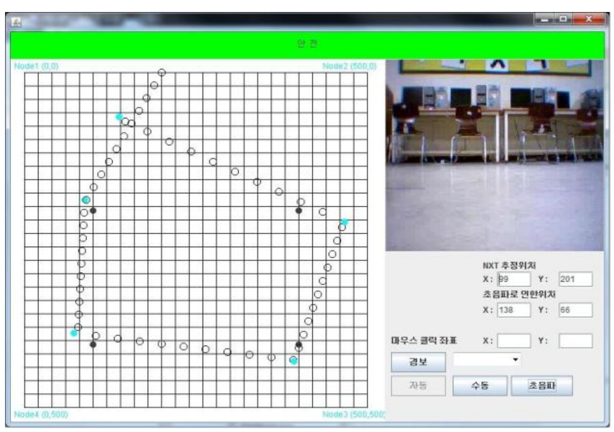

Figure 3. Screen image of navigation system by encoder only

5. Conclusions

In this paper a remote navigation system for mobile robot using USN and image information is proposed. It is not easy to obtain exact position of mobile robot from sensor information. To solve this problem we use ultrasonic sensors and rotate moving node which is attached to robot in 360 degrees. By experiment we can obtain exact distance values between reference nodes and robot, and estimate position of mobile robot more accurately. Experiment Results show that mobile robot navigates assigned path in certain area with small errors compared to navigation result by encoder information only. Max error is only 10 Cm. Web-camera sends real-time images of remote place and we can monitor it. When emergency breaks out, we can respond it quickly. By using this we can build a system for prevention of crime or disaster.

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