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The Local and Global Combine Method of UAV Indoor Location Technology

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Abstract: There are three main indoor localization technology: the optical, the radio (Wi-Fi, UWB, and Zigbee) and Ultrasonic. The paper focus on analyze the performance of the Ultrasonic and Zigbee location technology. In localization technology of Zigbee, the communication delay and packet loss will influenceits accuracy, and in Ultrasonic the obstacle will block its location process. So, the local and global combine technology of ZigBee based on RSSI is proposed and simulated in the paper.

Keywords: localization; Zigbee; Ultrasonic.

Introduction

There is a growing need to enable the UAVs (unmanned aerial vehicle) to do their missions autonomously. To accomplish these tasks, the location technology is fundamental, especially in indoor environment. It is obvious, that to locate a position, one need at least three independent measurements. And to improve the accuracy, more measurements is often undertaken to compensate thestochastic errors. In single UAV, the navigational information of IMU (inertial measurement unit), SLAM (Simultaneous localization and mapping) and Wi-Fi SLAM. In multiple UAV, the first way, each UAV acquired location information by Zigbee, Ultrasonic, and so on; then the positioning information is transmitted to the fusion center, then the center processes the data and transmit to other UAV. The second way, the distributed multi-UAVs cooperative localization algorithm, each UAV process the position information and do formation filter, then the filter results are sent to the leader. Below introduce some main position technologies[1]-[5].

Wi-Fi positioning system (WPS) measures the intensity of the received signal (RSSI) and uses the "fingerprinting" method to locate a position. In Wi-Fi location, the information of SSID and the MAC address are also gotten simultaneously to build a map of location. Bluetooth is only proximity location technology. It provides an indoor proximity solution. In passive radio-frequency identification (RFID) / NFC systems, they give location coordinates of the sensor or current location[6]-[10].

Zigbee, Infrared, Ultrasonic, and UWBuse beacon to locate the position. The methods include: 1) Angle of arrival (AoA); it uses the time difference of arrival (TDOA) between multiple antennas in a sensor array. 2) Time of arrival is the amount of time a signal takes to propagate from transmitter to receiver. 3) Trilateration calculation [11]-[15].

There are lots of researches to study the localization technology of Zigbee, mainly problem is how to eliminate the inaccuracy coming from the communication delay and packet loss; meanwhile lots of ultrasonic researches concern the obstacle block its location, and how to improve the accuracy.

The paper is arranged as follow: in Section II, the mathematical model of position is proposed, in Section III, the Scheduling solution is given, in Section IV, the simulation and experiment are presented, and conclusion is in Section V.

Mathematical Model

Problem Description

The environment is a set $\{A_1, A_2, ---, A_k\}$ of k rectangular areas Ai. The whole of Ai is a room want to located. The location controlof UAV is: a set of points of interest $P_i = \{p_1, p_2, ---, p_k\}$, one can control a fleet of UAVs moving with a constant speed v to stay in the pi. And the location problem is if a fleet of UAVs moving with a constant speed v in the pi, one can tell it location position coordinate of pi (x, y).

In ZigBee, this is also called as location of mobile nodes with the Anchors (normally four, three, and two anchors). In Ultrasonic, this location technology is different from automobile reversing radar.

The problem can also be simple described as formula (1) , For a time instance tiand a point of interest p. The objective of location is to minimize the expression

$$\Sigma_{i=1}^{n}|P_{ti} - P_{real}| \qquad (1)$$

where a discrete time model is assumed, t1 is the time at the beginning, tn at the end of the period, and |Pt1-Pt2| is distance between the real location and test location. For many UAV location, formula (1) is extended as (2) : propose there is m nodes in the networks.

$$\Sigma_{i=1}^{m}N_k\ (\Sigma_{i=1}^{n}|P_{ti} - P_{real}|) \qquad (2)$$

Then, there are some propose: (1) interested point can cover all area. (2) UAV can be assigned to one area at time ti. (2) each area, every time can be separated.

Normally, the AoA and TOA algorithm, can be applied, and the optimum location of UAVs k : A→N0 can be sought by a greedy algorithm based on an estimate of the average distance.

RSSI Calculation

Formula (3) determine the distance from the RSSI values. The two RF model is shown in Figure.1.

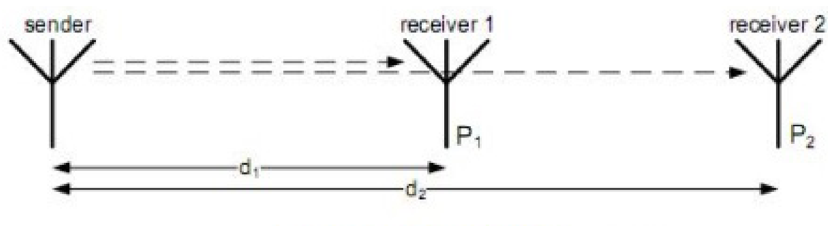

Figure1. *Free space path model.*

$$\frac{P1}{P2} = \left(\frac{d_2}{d_1}\right)^n \qquad (3)$$

Where: d1 is distance between receiver 1 and sender, d2 is distance between receiver 2 and sender, P1 is power at distance d1, P2 is power at distance d2.

$$P_2[dBm] = P_1[dBm] + 10n(lg(d1) - lg(d2)) \qquad (4)$$

$$RSSI = -(A + 10nlg(d)) \qquad (5)$$

In Static or low speed, the average RSSI is used. In dynamic or high-speed object, the Kalman filter is used. The experience formula is formula (6) or (7).

$$RSSI(d) = pt - 40.2 - 10 \times 2 \times lg(d),\ d \leq 8m \qquad (6)$$

$$RSSI(d) = pt - 58.5 - 10 \times 3.3 \times lg(d),\ d > 8m \qquad (7)$$

LQI and RSSI

The LQI and RSSI is used together to locate a position in Zigbee. In the paper, we only use RSSI method.

Scheduling Solution

The global and local location arithmetic is proposed use multi stage.

Stage 1: use 4 anchors and least square method to locate the position (static), one time, (x,y)

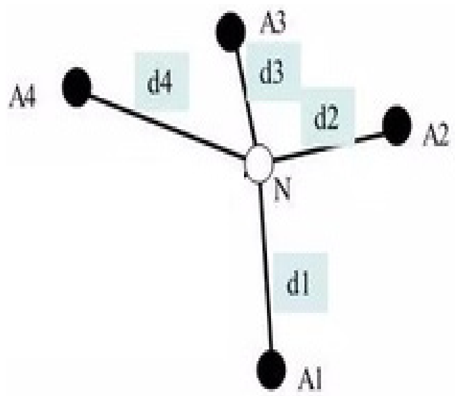

Figure2. *LS locationarithmetic model.*

Input : Ai(xi,yi), di (i=1, 2, 3, 4)

Output: (x,y)

The error equation is

$$\gamma_i = [(x - x_i)^2 + (y - y_i)^2]^{1/2} - d_i \tag{8}$$

We use matrix to represent the least square method, then

$$\mathbf{X = -(A^T A)^{-1} A^T L} \tag{9}$$

Stage 2: if UAV in static, use method of stage 1 more time and calculate the average position $(\overline{x,y})$

Stage 3: if UAV in dynamic, use method of stage 1, and local motion to calculate its relative motivation, then use the combine filter like formula (10) with α=0.1-0.7 to improve its accuracy.

$$X_i = \alpha \cdot X_i + (1 - \alpha) X_{i-1} \tag{10}$$

(1) Wired Ultrasonic Method

First, we use Ultrasonic to do global and local location of a board.

1) The boarduse local US-100 Ultrasonic module. It has the sender and receiver part in module.

2) There are two anchors, they send signal, and the four modules are connected to an MPU. then

a)do global location with the anchors send and local module receive.(TOA method)

b) board move, and its motivation is tested use US-100 Ultrasonic module separately. (TOA method)

c) global and local location arithmetic to locate the position.

d)do a)-c) more times.

3) Output the coordinate.

(2) Wireless Zigbeemethod

For the wired method is hard to accomplished in UAV, here we use Zigbee. The procedure is described below.

1) The Zigbee nodes in UAV is sink, the nodes use as anchors is End nodes or Routers.

2) The anchors send signals when receive signal to itself. The send interval of anchors is 10-30ms.

3) The nodes in UAV, receive the signal, and judge if all the signal are received. If it were true, it calculate the coordinate (xi,yi) use RSSI, use formula (3)-(7)

4) calculate the coordinate uses formula (8)-(9).

5) use global and local location arithmetic to calculate the moved UAV, with the local location of optical flow sensors or IMS.

(3) Termination Conditions

In general, the iteration number is determined by desired accuracy. In addition, it is also can be determined by the time used.

Simulation and Experiment

Wired Ultrasonic Method

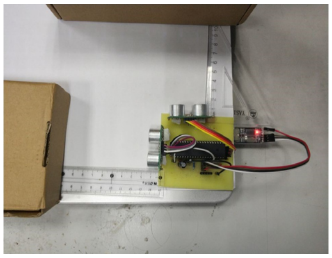

Figure3. *local location model of Ultrasonic*

We use the Ultrasonic to locate, the precision of position of local and global is almost less than 0.2cm.

Simulation of Zigbee

Here we use grey prediction algorithm to calculate the distance by RSSI (shown in Figure.4). it is able to reduce the fluctuation of RSSI when mobile is moving. Location algorithms with grey prediction achieve smaller mean distance error.

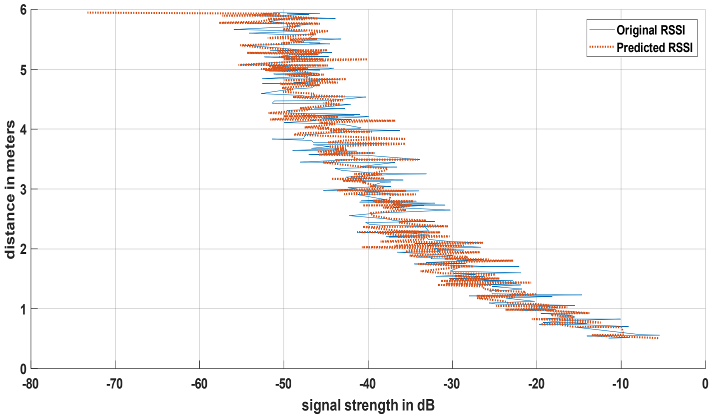

Figure4. *The relationship between distance and RSSI*

The simulation parameter of global location arithmeticis shown in Figure.5, some parameters are:

- number of anchors : 4
- number of mobile nodes: 1
- the anchor coordinates are (0,0), (50,0), (100,0) and (0,50).

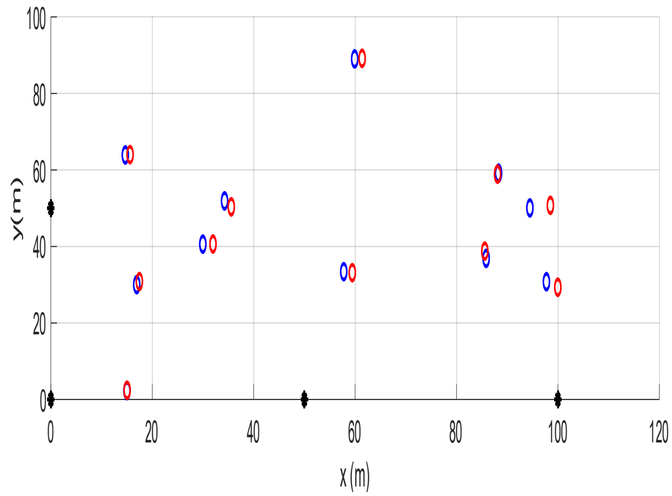

Figure5. *simple global location technology of Zigbee*

The simulation parameter of global and local location arithmeticis shown in Figure.6:

1) number of anchors : 4
2) number of mobile nodes: 1

- the anchor coordinates are (0,0),(50,0),(100,0) and(0,50)
- The move of local is along with the diagonal

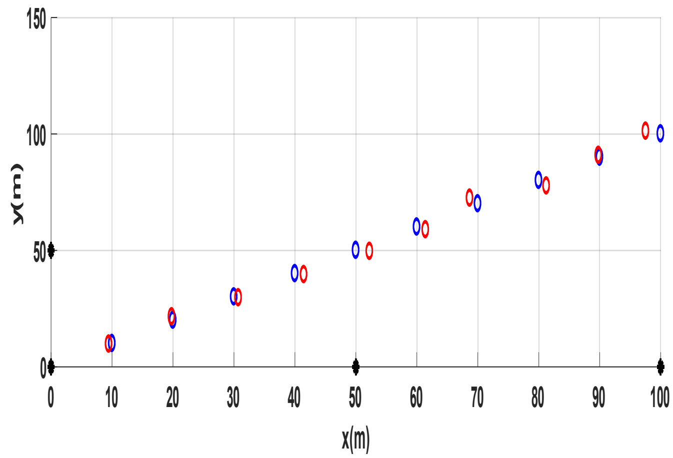

Figure6. *The global and local location technology of Zigbee*

Results

As shown in Figure.6, the accuracy of global and local location technology of Zigbee (precision is 1meter) is better than simple global location technology of Zigbee (precision is 2 meter).

Conclusion

In localization technology of Zigbee, the communication delay and packet loss will influence its accuracy, and in Ultrasonic the obstacle will block its location process. The paper propose the local and global combine technology of ZigBee based on RSSI, and the precision is improved than a single global location technology of Zigbee.

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