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Mitigating NLOS Error for UWB Positioning System

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Abstract

The Ultra-Wideband Positioning System service of wireless communication industry has become a popular issue in the recent years. This service can provide an accurate location for many useful functions. The main problem that causes the two major errors are: measurement error, and NLOS (Non-line-of-sight) error. Especially the NLOS errors have the most serious effect on mobile position system. This paper will put a high emphasis on how to mitigate the error caused by NLOS. The simulation results show that the proposed algorithm can reach a high accuracy even in a severe environment.

I. Introduction

Ultra-Wideband position system has become a very hot topic in wireless communication system, because it enables us to locate immediately where the user is. In present, techniques of position system are TOA (time of arrival), AOA (angle of arrival), TDOA (time difference of arrival), and the Hybrid technique that combines TOA with AOA [1]-[3]. But the accuracy of these techniques had been greatly biased by NLOS propagation [4]. The NLOS effect is mainly from the diffraction, scattering, and refraction. NLOS error mitigation techniques have been investigated extensively in the literature [5]-[18]. In order to increase the measurement accuracy, we have to find out a better algorithm to reduce the NLOS effect.

In the UWB position system, TOA and AOA techniques need more than two base stations to get a position data, and the hybrid TOA/AOA technique just needs one base station to get a position data. Therefore, we propose a new data selection algorithm based on the hybrid TOA/AOA technique.

In Section 2, we will introduce the basic calculation model of TOA. In Section 3, we will present our formula which can diminish the errors of NLOS. Then, simulation results will be shown in Section 4. Finally, some conclusions are drawn in Section 5.

II. The basic model

In the mobile positioning process, the measured distance between base station (BS) and mobile station (MS) can be written as:

$$r_m = d_m + r_m^n + r_m^{NLOS}$$

r_m and d_m are the measured distance and the actual distance from MS to the m^{th} BS, respectively. r_m^n is the m^{th} measurement error and r_m^{NLOS} is the NLOS error. Note that the superscript "n" and "NLOS" denote the measurement error and the error caused by NLOS, respectively.

Similarly, the angle of arrival between BS and MS measured by each BS can be written as [4]:

$$\theta_m = \phi_m + \theta_m^n + \theta_m^{NLOS}$$

Where θ_m is the angle of arrival measured by the m^{th} BS. ϕ_m is the actual angle between MS and the m^{th} BS. θ_m^n is the m^{th} measurement error. θ_m^{NLOS} is the NLOS error, and the range of θ_m^{NLOS} is from 0 ~ 2π .

III. NLOS mitigation

Since the algorithm presented in this paper is based on the Hybrid positioning technique, we are going to introduce the Hybrid (TOA/AOA) positioning technique briefly here.

It only takes one base station to calculate a positioning result by the Hybrid positioning technique. First, we can get the distance d and the angle θ from the measurement of the BS. By taking the BS and d as the center and the radius, we can draw a circle, and lengthening a line of the angle θ from the base station. The lengthening line will cross a point with the circle and the intersection point is the position result of MS.

In the Hybrid positioning technique, every BS can get a position data. If we want to have an accurate result, we have to get rid of all possibilities that it might be affected by NLOS effect. The measurement distance and angle will be influenced greatly by NLOS effect. In order to mitigate the NLOS effect, we adopt more base stations for one simulation. In a two-dimensional plane, all the position data will distribute surround the true MS location theoretically. If the base station is under large NLOS error or large measurement error, the position data will be far away from the true MS location. (P1, P4 and P5 in Fig.1.) In other words, position data which are lightly influenced by NLOS or measurement error should be intensively distributed around the true MS location (P2, P3, P6, and P7 in Fig.1.), as shown in Fig.1. As a result, we shall remove the position data which were affected by large errors and only need the intensively distributed position data. Then more accurate result can be obtained by only using the intensively distributed position data.

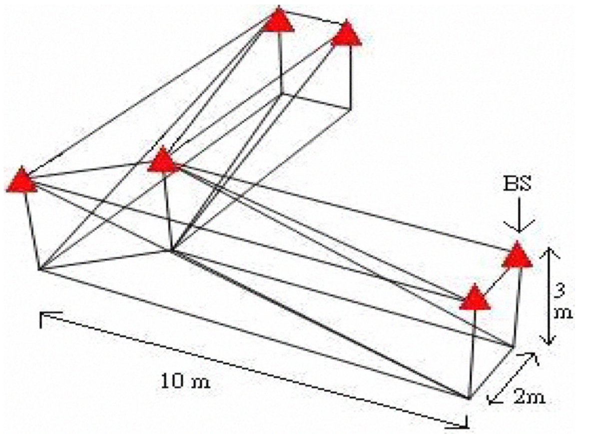

Fig.1. The diagrammatic sketch and the distribution about MS..

The following procedures and assumptions are made to develop our proposed algorithm:

1. We assume "α" BSs in our simulation. In the Hybrid technique, each BS is used to predict the position of the MS. Let P_m denote the positioning result from the m^{th} BS, and m is from 1 to α. Then, we totally have α results. ($P_1, P_2, P_3 ..., P_\alpha$).
2. Let $d_{(u,v)}$ be the distance between P_u to P_v, and $u = 1 \sim \alpha, v = 1 \sim \alpha$. We calculate $d_{(u,v)}$ and more close the position result is, more small the $d_{(u,v)}$ will be.
3. Calculating $\delta^u = \sum_{v=1}^{\alpha} d_{(u,v)}, u = 1 \sim \alpha$
4. Sorting δ^u according to its value in descending rule. (Example： if $\delta^3, \delta^2, \delta^4, \cdots, \delta^1$, then $P_3, P_2, P_4, \cdots, P_1$)
5. Summation the sorted first 3 position data and average them as a final position result. (The reasons why we only adopt three position data were written below)
    1. We do not know how many BSs were affected by NLOS, so we have to assume that almost all BSs were effected, which means the LOS position data would be in quite few amount. In order to higher the tolerance of NLOS effect, we have to adopt fewer positioning data as possible.
    2. If we try to find out the true MS position, using only one or two reference position data would bias the position location result and cause larger error. Therefore, using three position location data is our best choice.

In this procedure, we do not care whether the error caused by NLOS and measurement was large or not. Because when all the positioning data are small error, this algorithm will bring us more accurate results without doing anything else.

IV. Simulation results

In this section, we will test our proposed algorithm on mitigating NLOS error by computer simulation. Several different situations are considered, and for each situation 1000 times simulations are taken. The location of MS is randomly assigned within the coverage of the cell. The proposed algorithm is also compared with the other three position algorithms (LOS Relative and Whole algorithms).

First, we simply introduce the LOS and Whole Algorithms：

(1)LOS algorithm：

In this algorithm, the Line-of-Sight position data are only used to predict the MS location. This algorithm is an ideal case, because we can not know what BS is affected by the NLOS effect. In order to compare with all algorithms, we have to assign some specific BSs affected by the NLOS effect. This will not affect the accuracy of all algorithms. In our simulation, we assign BS1, BS3 and BS4 as BSs with LOS effect.

(2)**Whole algorithm**：

All the position data are adopted and without any NLOS error mitigation.

(3)**Relative algorithm :**

As reference [19], we take it's concept, in order to compare fairly, reconstruct this algorithm base on Hybrid AOA/TOA technique.

The main approach we use to judge every formula's performances is Root Mean Square Error (RMSE):

$$RMSE = \sqrt{\sigma_x^2 + \sigma_y^2}$$

σ_x^2 and σ_y^2 are the variance of the X and Y axis in Cartesian coordinates.

In our simulation, we assume the measurement error of the angle and distance range are 1 degree and 19cm, respectively. The NLOS angle error is uniformly distributed, and its range is from $-\pi$ to π.The average range of NLOS distance error and standard deviation are 239cm and 148cm, respectively. The error value was from simulated program in L-shape corridor. The simulation environment in a L-shape corridor, wide 2 meter, height 3 meter, and length 10 meter. Each BS is in the corner of corridor. It takes 6 BSs to simulate in this cases. The RMSE error of the three cases is shown in Table.1.

From this simulation case, we can find that the performance of the proposed algorithm is sometimes better than the Relative algorithm, and the RMSE error of LOS and the proposed algorithm is quite close.

It is obviously that, from the simulation results, the proposed algorithm can be as accurate as LOS algorithm. Also, the proposed algorithm can tolerate high proportion of NLOS BSs.

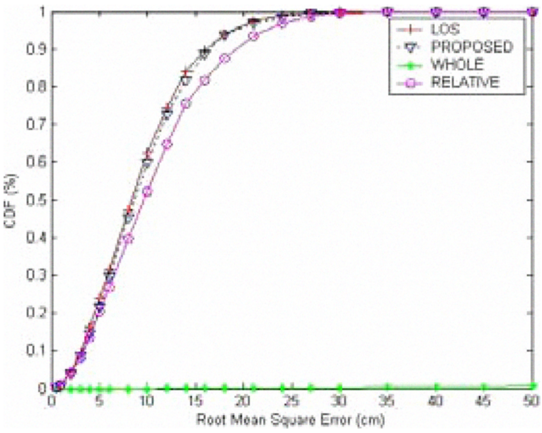

Fig.2. The simulation result

Table 1. RMSE of simulated cases (meter).

	RMSE (cm)
Whole algorithm	1.4189e+003
Line-Of-Sight algorithm	58.9142
Proposed algorithm	9.4010
Relative	10.4826

V. Conclusions

The proposed algorithm gives a high accurate estimation of mobile location without any prior knowledge about the NLOS information, and the accuracy between proposed algorithm and LOS algorithm is very close. This algorithm can be easily extended to get the NLOS probability of each BS.

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