Successive Position Estimation Method for Multiple Object using UWB signal

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***Abstract* - In indoor position estimation, it is necessary to consider multiple objects. This paper proposes a successive position estimation method for multiple objects using UWB signal. Further, estimation accuracy of the proposed method is evaluated. It is shown that the number of objects is increased, the estimation accuracy is reduced. It is also shown that the estimation accuracy less than 0.05m is obtained in 85% of cumulative probability when the number of objects is 4.**

***Index Terms* - UWB signal, Position estimation, Multiple objects, Successive estimation.**

1. Introduction

In recent years, various indoor position estimation techniques for purpose of security or monitoring are proposed [1]-[3]. In the techniques, it is necessary to consider multiple targets. This paper proposes a successive position estimation method using the UWB signals for the multiple objects.

2. Proposal of multiple object position estimation method

(1) Position estimation using reception time difference

A transmitting antenna radiates UWB short pulse as shown in Fig. 1. The wave is reflected by objects and received by receiving antennas. A receiving time difference between adjacent elements correspond to the distance difference from the object to the receiving antennas. Hyperbolas are drawn from the distance difference as shown in Fig. 1. Two hyperbolas can be obtained using plural receiving pair. Then, the intersection of the hyperbolas correspond to the position of the object.

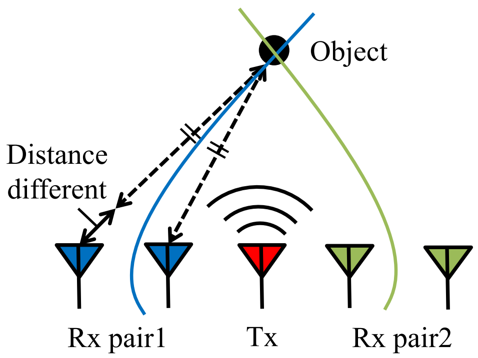
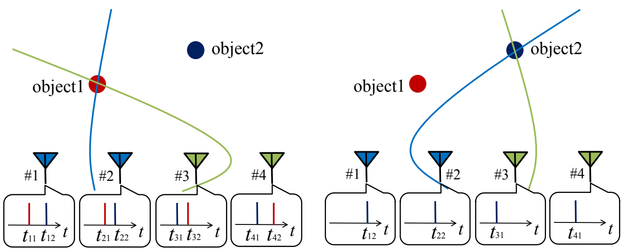


Fig.1. Object Position and Hyperbolas

(2) Successive position estimation method for multiple objects

Fig.2 shows an overview of the successive position estimation method. The reception time t_{nm} (n=1,2,..., N, m=1,2,..., M) is measured at each receiving antenna. Here, N is the number of the receiving antennas, M is the number of the objects.

Two receiving pairs are selected, and the first object position is estimated using hyperbolas from the reception time difference as shown in Fig. 2(a). If the estimated position is correct, information of the estimated object in each element is removed as shown in Fig. 2(b). Then, the next object position is estimated using remaining information. If the estimated position is incorrect, the position estimation is repeated with changing the combination of the reception time difference and the receiving pairs.



(a) First object estimation (b) Second object estimation

Fig.2. Overview of successive estimation

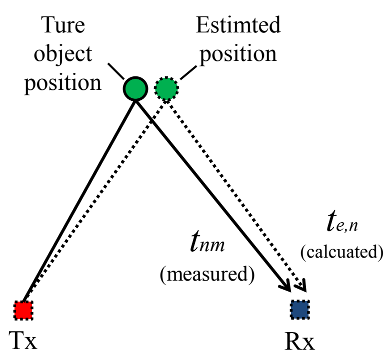


Fig.3. Accuracy judgment

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(3) Accuracy judgment method for estimated position

In the successive position estimation mentioned in 2.2, it is necessary to judge the estimated position is correct or not. Fig.3 shows an overview of the accuracy judgment method for the estimated position. The reception time $t_{e,n}$ of the reflected wave from the object is calculated at each receiving antenna using the estimated object position, and t_{nm} is measured reception time. t_{th} is the allowable error of the received time between t_{nm} and $t_{e,n}$. If Eq. (1) is satisfied for all receiving antennas, it is judged that the estimated position is correct.

$$| t_{nm} - t_{e,n} | \leqq t_{th} \qquad (1)$$

3. Analysis model for evaluation

Fig.4 shows an analysis model. The receiving pair consist of the two antennas is arranged in four corners. The multiple objects are located in the analysis area. (x_m, y_m) is the position in m-th object, d is element space of the element pair. Here, d = 0.7m, the analysis area is 5m × 5m.

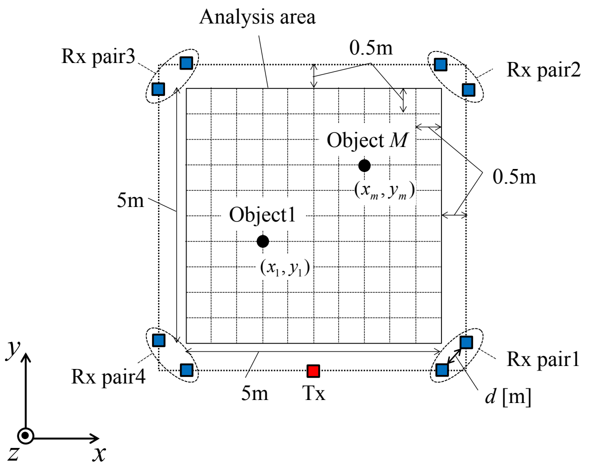

Fig.4. Analysis model

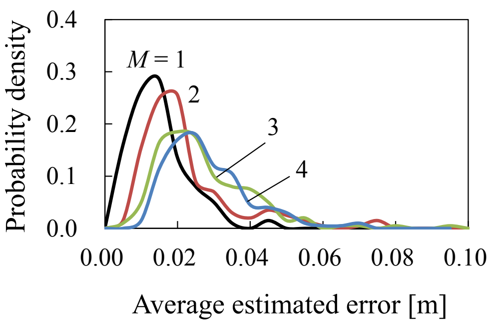

Fig.5. Probability density
of averaged estimation error

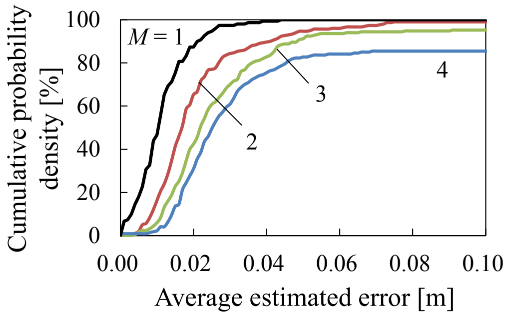

Fig.6. Cumulative probability density
of averaged estimation error

4. Position estimation accuracy for multiple objects

Fig.5 shows the probability density of the averaged estimation error of the successive position estimation method for multiple objects. Fig.6 shows the cumulative probability density. Parameter is the number of the objects M. The object is arranged at random in the area. The antenna has omnidirectional pattern. The center frequency and bandwidth of the UWB signal is 4.6GHz and 3GHz, respectively. Here, t_{th} = 0.5 ns. Thermal noise in the receiving antenna is not taken into consideration.

From Fig.5, it can be seen that the average estimation error is small when M=1, and that is decreased as the number of objects is increased. From Fig.6, it can be seen that the estimation accuracy is decreased as the number of objects is increased. This is because that there are cases where correct reception time can't be obtained due to interference between the objects as the number of objects is increased.

5. Conclusion

This paper proposed a successive position estimation method for multiple objects using the UWB signal. As the number of objects was increased, the estimation accuracy was reduced. It was shown that the estimation accuracy less than 0.05m was obtained in 85% of cumulative probability when the number of objects was 4.

References

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