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Wireless sensor network positioning based on the unilateral side of two reference nodes [☆]

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ABSTRACT

We propose a new theory and method for unilateral positioning based on two reference nodes to reduce the number of reference nodes used in unilateral node deployment. In the method, a blind node obtains the location and distance of two reference nodes by establishing equations intended to derive two sets of solutions. The positioning solution of the blind node is then determined on the basis of one side of the line that connects the two reference nodes. To verify the accuracy of the new method, the proposed positioning theory is interpreted and simulated in a MATLAB environment. Results show that the highly accurate positioning generated by the proposed method is attributed to its basic principle and right method, thereby reducing the number of reference nodes needed for positioning in wireless sensor networks.

1. Introduction

The geometric positioning algorithms used in wireless sensor networks include the trilateration, triangulation, and multi-trilateration methods [1–3]. Localisation techniques based on multi-dimensional scaling and stochastic proximity embedding transform a mathematical model to convert distance information into a coordinate vector [4]. These node positioning methods are used for a large number of distributed reference nodes because many of these nodes present arrangement problems and high costs [5]. Traditional geometric range-based localisation techniques require three or more reference nodes obtained from prior knowledge, such as distance, time difference in arrival, angle of arrival, and connectivity.

This study contributes to existing literature in that it proposes a new positioning approach that is based on the unilateral side of two reference nodes, in contrast to other methods that use three reference nodes. A layout with a small number of reference nodes presents low cost and easy node deployment. The new method may be used in positioning applications, such as vehicle positioning on highways and mine personnel localisation [6,7], for which the unilateral deployment of two reference nodes may reduce the number of required reference nodes. Similarly, using two reference nodes in calculations improves positioning efficiency and maintains positioning accuracy.

The rest of the paper is organised as follows. In Section 2, we discuss the concept of unilateral reference node deployment. In Section 3, we introduce the theory of two-reference node positioning. Section 4 presents the design of the positioning method, and Section 5 discusses the experiments and results. Section 6 presents the comparison between the proposed method and other localisation techniques, and Section 7 concludes the paper.

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2. Unilateral reference node deployment

The deployment of unilateral reference nodes requires that all positioning nodes (called blind nodes) be located on the other side of fixed reference nodes to enable the separation of all blind and reference nodes (known location) by a segmentation line. Fig. 1 shows that blind (unknown location) and reference nodes are separated by the ABCDEFG curve, and that all the reference nodes allocate the order identifier ID. The blind nodes are located on the left side of the reference nodes if the segmentation curve from points A–G is used as the reference direction, or if the ID increases along this direction. The blind nodes are located on the right side of the reference nodes if the segmentation curve from points G to A is used as the reference direction or if the ID decreases along this direction. The segmentation line is a straight line if ABCDEFG is also a straight line.

3. Theory of two-reference node positioning

Fig. 2(a) shows that the coordinates of two reference anchor nodes are A(x_a,y_a) and B(x_b,y_b), and that of an unknown location blind node is P(x,y) or Q(x,y). We assume that the distances from unknown location blind node P or Q to reference anchor nodes A and B are d_a and d_b, respectively. Thus, the distance between two points can be deduced by

$$\begin{cases} \sqrt{(x-x_a)^2+(y-y_a)^2}=d_a \\ \sqrt{(x-x_b)^2+(y-y_b)^2}=d_b \end{cases}. \tag{1}$$

The x and y coordinates of point P can be obtained through solving Eq. (1).

When the distance is:

(1) PA + PB > AB, Eq. (1) has two sets of solutions. Fig. 2(a) shows that points P and Q are solutions that satisfy Eq. (1).
(2) PA + PB = AB, Eq. (1) has a unique solution. Fig. 2(b) shows that points P and Q are superposed.
(3) PA ± AB = PB, Eq. (1) also has a unique solution. As shown in Fig. 3(a) and (b), points P and Q are superposed.

The straight line equation that runs through points A and B is

$$f(x,y)=y-y_b-k(x-x_b), \tag{2}$$

where

$$k=\frac{y_a-y_b}{x_a-x_b} \tag{3}$$

is the slope of the line.

3.1. Positioning principle for the same solution

As shown in Figs. 2(b) and 3(b), if the blind node in the connection line of points A and B has an assumed solution of C(x_1,y_1) or D(x_2,y_2) (superposed), then this node satisfies

$$f(x_1,y_1)=0 \quad \text{or} \quad f(x_2,y_2)=0. \tag{4}$$

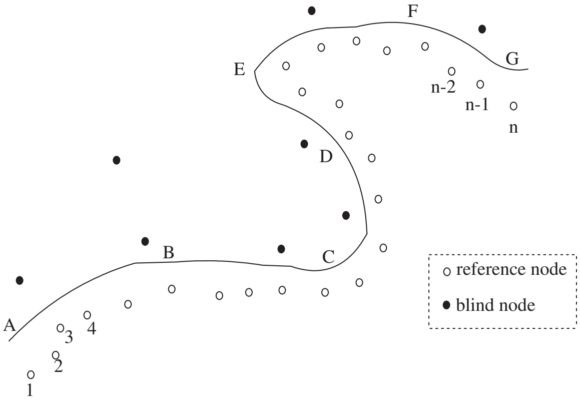

Fig. 1. Node distribution in segmentation area.