Analysis of Location Tracking based on Friendly Points

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Abstract: This paper presented and analyzed a location tracking scheme based on friendly points. A set of friendly points provides with a convenient and accurate location information for mobile tracking. The scheme partitions the target area to reduce the error. The friendly points are selected such that inter distance among the three intersection points is the minimum. The simulation based on the proposed scheme shows some promising output. It reduces the maximal and average errors by 43.25% and 44.59%, respectively. This scheme can be used for wireless sensor network applications where multiple observation facilities are available.

Key-Words: Friendly points, location tracking, tracking, location, triangulation.

1 Introduction

Location tracking becomes a major feature of recent mobile devices[1]. Triangulation has been the standard for locating moving objects. Location methods such as TOA(Time of Arrival) and TDOA (Time Difference Of Arrival) employ triangulation [2,3,4].

Conventional methods suffer the maximal error occurred in measurement yielding somewhat incorrect location information[5,6]. Minimal measurement error brings the accurate location information. Errors in location calculation should be under control for practical applications. The large target area should be partitioned into a smaller area to lower the errors.

The friendly points introduced in this paper limits the magnitudes of measurement error within a controllable range. Relative errors can be reduced by using the friendly points within a target area. This algorithm can be used for wireless sensor networks where their operating condition is relatively poor.

Section 2 of this paper surveys the conventional location schemes based on triangulation, and Section 3 proposes a new algorithm based on friendly points. Section 4 analyzes the proposed algorithm, and finally Section 5 concludes with evaluation.

2 Conventional Location Tracking Methods

Typical location tracking methods based on triangulation are TOA and TDOA [2,3,4]. These employ distance measurements for mobile networks, GPS and sensor networks. Triangulation methods are the circular LOPs (line of positions) and straight LOPs algorithms.

Circular LOPs algorithm estimates the location of the target based on some predetermined parameters and measured distance[7]. The location of the target is the intersection of the three circles as shown in Fig. 1. Distance assums to be measured linearly without any errors involved. The measured location can be represented in (1). *D, O(x,y),* and *P(Xs, Ys)* represent size the measured distance, observer points, and measured locate, respectively.

$$D_i = \sqrt{(x_i - X_s)^2 + (y_i - Y_s)^2}\ , (i = 1,2,3...) \qquad (1)$$

The straight LOPs algorithm yields the location information based on the intersection of straight lines associated with circles and predetermined parameters and distance data[8]. The straight line is defined when two size circles intersects. When two circles do not intersect, the distance between the circles is divided by the ratio of distance measured. The total number of the straight lines is one less than the number of observers. The measured location can be represented in (2). Figure 1 shows the circular LOPs algorithm with circles and the straight LOP algorithm with straight lines.

$$(x_2 - x_1)X_s + (y_2 - y_1)Y_s = \frac{1}{2}(|x_2|^2 - |x_1|^2 + D_1^2 - D_2^2)$$
$$(x_3 - x_2)X_s + (y_3 - y_2)Y_s = \frac{1}{2}(|x_3|^2 - |x_2|^2 + D_2^2 - D_3^2) \quad (2)$$

where

$$D_i = |x_i - X_s| = \sqrt{(x_i - X_s)^2 + (y_i - Y_s)^2}$$

The foregoing algorithms may suffer from measurement errors and thereby yield inaccurate location data. The distance data may include contributions from signal distortion, reflection and fading, when the measuring signal passes through the medium. The magnitude of the errors may grow as the distance measured increases. Figure 2 shows the consequences of the error in location tracking based on the circular and straight LOPs algorithm.

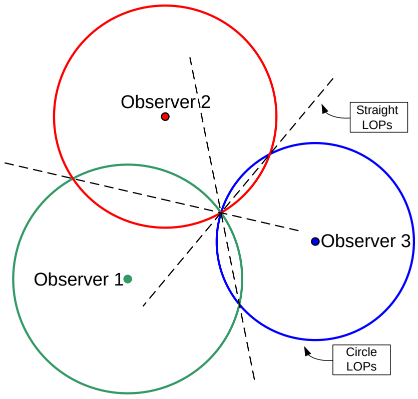


Figure 1 Circular and straight LOPs algorithms

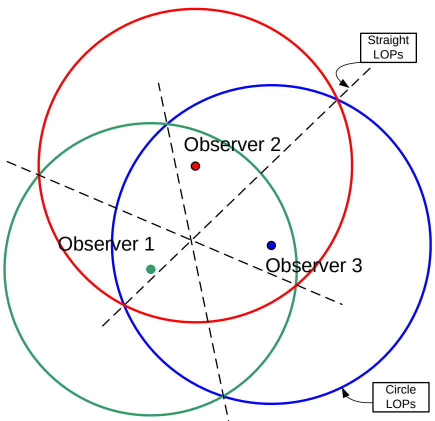


Figure 2 Location tracking associated with measurement error

3 Proposed Method of Location Tracking

The proposed method is based on the proximity points to reduce the influence of the associated error. Calculation of location employs the same parameters and equations as the conventional methods. The location of the target is calculated using the observer position and distance to the targets. The relative error may exist in the raw data. The location of the target is obtained from the proximity points deduced from the measurements.

3.1 Background

Measurement error increases along the distance from a observer to the target. The error gets smaller as the differences among measurements decreases. Figure 3 shows the cases suffering errors higher than tolerable ranges. Conventional scheme takes the area 2 as the target area. The area 1 may find the target for some relative error involved. The probability of the target location reside in the Area 1 grows along the size of the Area 2. The relative error may increase along the increase of the measured distance.

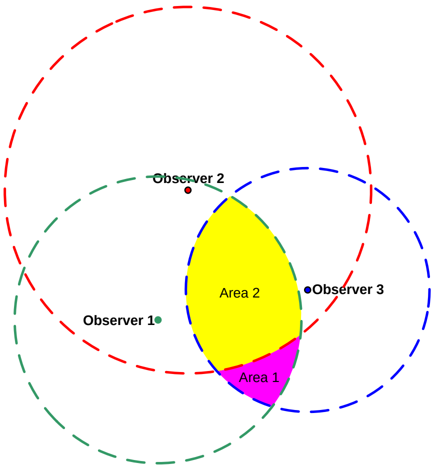


Figure 3 Ranges of the target based on distance measurement from an observer

3.2 Algorithm

The proposed scheme based on friendly points addresses the case for the target located in the Area 1. The location tracking employs the circle defined by the observer coordinates and the measured distance. The measured distance can be represented in (4). L, l, and Δl representing the measured distance, actual distance and the error associated with the measurement, respectively.

$$L_i = l_i + \Delta l \ , \ (i = 1,2,3...) \qquad (4)$$

The intersections $N(N_x, N_y)$ of the circles defined by the measured distance and the observer positions are calculated using (5).

$$N_x = x_i + L_i \cos\theta$$
$$N_y = y_i + L_i \sin\theta$$
where
$$\theta = \varphi \pm \cos^{-1} \frac{r_1^{\ 2} - r_2^{\ 2} + D^2}{2a_1 D} \qquad (5)$$
$$D_i = \sqrt{(x_i - X_s)^2 + (y_i - Y_s)^2}$$
$$\varphi = \tan^{-1} \frac{(b_2 - b_1)}{(a_2 - a_1)}$$

Table 1 Intersections of circles from observers

Intersections of observers O_1, O_2 : N_1, N_2
Intersections of observers O_2, O_3 : N_3, N_4
Intersections of observers O_3, O_1 : N_5, N_6

The selection of friendly points are as follows in phase. The variables *size* and *case* in the following procedure represent the total distance and the selected intersections, respectively. Figure 4 shows the selection of three points.

Phase

for i = 1:8
size[i] = function(case[i])
if (min(size[i]))
case[i]
end
where
function(point[3])= $D_{N_1N_2} + D_{N_2N_3} + D_{N_1N_3}$

The equation 6 yields the location of the target using the friendly point coordinate values derived in the (5).

$$Locate = \frac{\overline{P_1P_2} \times P_3 + \overline{P_2P_3} \times P_1 + \overline{P_1P_3} \times P_2}{\overline{P_1P_2} + \overline{P_2P_3} + \overline{P_1P_3}} \qquad (6)$$

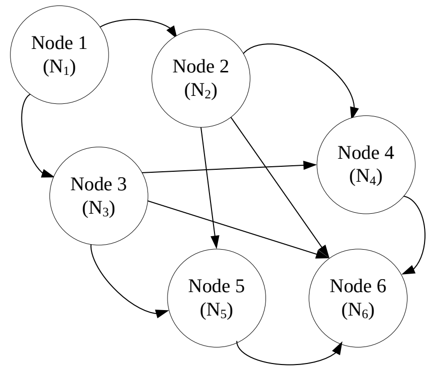


Figure 4 Selection of three points among the intersections of circles

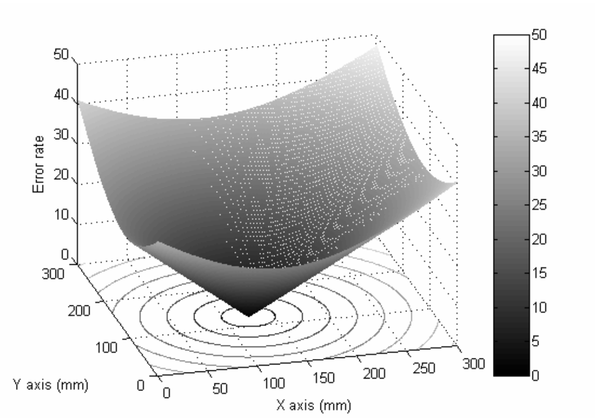
4 Simulation and Performance Analysis

Conventional location tracking systems cover wide areas with multiple observers. The TOA or TDOA partitions the target areas with fuzzy or mesh architecture. Each partitioned area has a triangular shape with multiple observers [5,6]. The simulation performed in this research has three assumptions: the first, the LOPs algorithm experiences less error when the target approaches circumcenter of a triangle defined by the three observers; the second the proposed scheme suffers less error when the target locates inside the triangle defined by the three observer; and finally the error becomes smaller as the target approaches one of the observers.

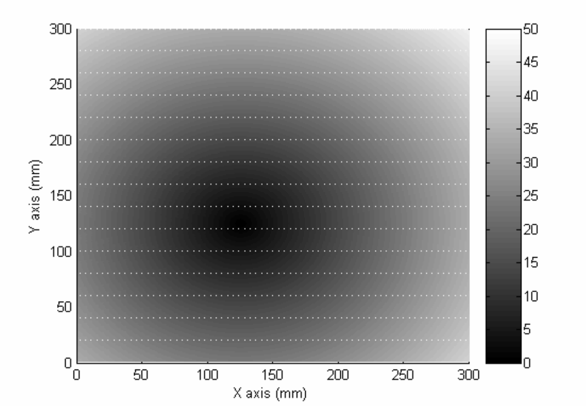
The simulation evaluates the performance of the proposed scheme based on friendly points. This scheme uses the position data of observers and measured distance values between the target and an observer. The observer positions are predetermined. The measured data comprises relative errors due to the measurement condition.

The simulation parameter comprises the observer coordinates and the distance from the observers. The observers assume at the coordinates of (0 ,0), (300 ,100) and (100 ,300) in a rectangular cell of the size 300 x 300. The target assumes a 1x1 cell within a triangle of the three observer coordinates. The measured distance assumes errors with average 0 and variation of 1 under AWGN (Additive White Gaussian Noise) distribution.

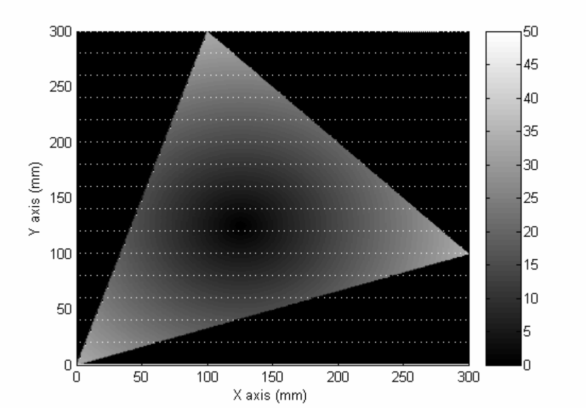
The simulation has been performed on the conventional and the proposed schemes yielding error estimation. The maximal errors are shown in Fig. 6 as the target moves along the x and y axes. The performance evaluation is summarized in Table 2. The proposed scheme based on friendly points reduces the maximal error by 43.25% and the average error by 44.59% in triangle area compared to the conventional scheme. The simulation confirms the simulation assumption: less error observed as the target approaches the observers. The proposed scheme found effective when it is used inside the triangle of the observer coordinates.



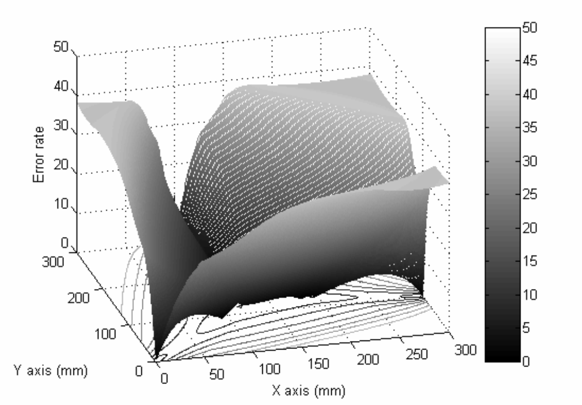
a) **Triangulation method of 3D in all the area.**



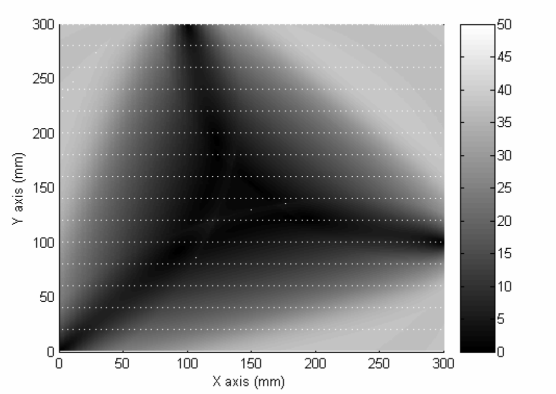
b) Triangulation method of 2D in all the area



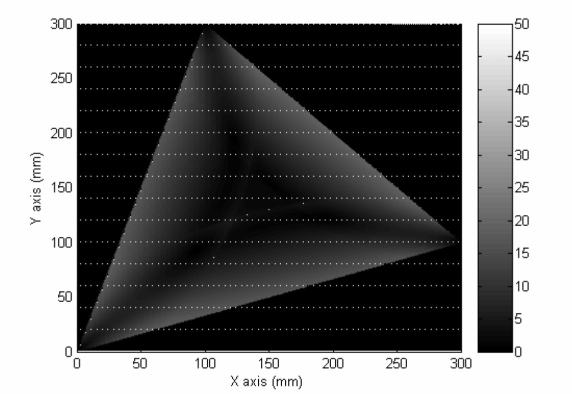
c) Triangulation method of 2D in the triangle area.



d) Friendly-points method of 3D in all the area.



e) Friendly-points method of 2D in all the area.



f) Friendly-points method of 2D in the triangle area

Figure 5 Simulation results

Table 2 Performance of the friendly points algorithm

Error rate(%) \ Method		Triangluation	Friendly-points	Relative improvement
Maximal error	All area	47.02	38.82	19.2
	Inside the triangle	33.39	18.95	43.25
	Outside the triangle	57.42	49.31	15.13
Average error	All area	22.53	20.46	9.92
	Inside the triangle	15.49	8.60	44.59
	Outside the triangle	28.11	29.86	-6.2

5 Conclusion

The proposed tracking algorithm reduces the location error based on friendly points. The target area has been partitioned through fuzzy logic or mesh architecture. Then it estimates the target location within a partition. The proposed scheme based on friendly points selects three points with minimal sum of inter-point distances. The proposed scheme reduces the maximal and average errors by 43.25% and 44.59%, respectively. This scheme can be used for wireless sensor network application where multiple observations facilities are available.

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