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The Simulated Location Accuracy of Integrated CCGA for TDOA Radio Spectrum Monitoring System in NLOS Environment

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ABSTRACT— ***Since the multipath effect is usually occurred in metropolitan area, the location error resulting from non-line of sight (NLOS) is appeared and then significantly decay the location accuracy of time difference of arrival (TDOA) radio spectrum monitoring system. In this study, the proposed integrated cross-correlation and genetic algorithm (integrated CCGA) scheme for previous works by current authors was investigated and evaluated under NLOS environment. In current simulation before the practical experiment in the future work, the location accuracy of proposed CCGA is approximately same as those of the conventional Fang approaching while transmitter (i.e, is referred as interference station) is located on the geographical position of inside of TDOA coverage area. In addition, the location accuracy of proposed CCGA is significantly better than those of the conventional Fang approaching while transmitter is located on the geographical position of outside of TDOA coverage area. Even though in NLOS environment, the simulation results show that the proposed scheme is easily to identify, locate, and remove radio interference resulting from low transmission power, burst and weak signals, or metropolitan.***

Keywords—Time difference of arrival (TDOA), Integrated cross-correlation and genetic algorithm (integrated CCGA), Non-line of Sight (NLOS), Radio Spectrum Monitoring System (RSMS).

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1. INTRODUCTION

TDOA-based location technology involves two main processes, namely cross-correlation and solving hyperbolic algorithms [1]. Fang have presented numerous methods for solving nonlinear hyperbolic algorithms [2]. To improve the location accuracy of previously proposed TDOA-based monitoring and location systems [3], the integrated cross-correlation and genetic algorithm (integrated CCGA) scheme was proposed for previous works by current authors to compare the practical experiment results [1, 3]. However, the multipath effect is usually occurred in metropolitan area. Hence, the location error resulting from non-line of sight (NLOS) is appeared and then significantly decays the location accuracy of time difference of arrival (TDOA) radio spectrum monitoring system [4-5]. In order to realize the locating capability of proposed integrated CCGA scheme for identifying, locating, and remove radio interference resulting from low transmission power, burst and weak signals, or metropolitan, the location accuracy of proposed CCGA was investigated and evaluated before the practical experiment in the future work.

The remainder of this paper is organized as follows: Section 2 presented TDOA Scheme with Genetic Algorithm under Non-line of Sight Scenario. The simulation of various the locating approaching of Fang and proposed integrated CCGA algorithm is demonstrated and compared in NLOS environment in Section 3. Finally, Section 4 presents the conclusions.

2. THE TDOA SCHEME WITH GENETIC ALGORITHM UNDER NLOS ENVIRONMENT

A genetic algorithm (GA) treats each potential solution of a problem as an individual, represented by a string of parameter values in a binary form. In the GA, the suitability of each chromosome as a solution to the optimization problem is indicated by its fitness value, as determined from an objective fitness function. The GA commences by establishing an initial population pool of randomly selected chromosomes. The phases and steps of the GA approach are described as follows.

(Step 1) Parameter setting phase: Input: population size=20, crossover rate=0.8, mutation use Gaussian function, reproduction rate=0.1 and generation number=1000. Output: the optimal chromosome and fitness value.

(Step 2) Initialization phase: an initial population is generated. The fitness values of the population are then calculated.

(Step 3) Crossover operation phase: The scattered method as a crossover operation is employed here. The probability of crossover is determined by crossover rate simultaneously.

(Step 4) Fitness: Calculate the fitness value in the simulation processing.

(Step 5) Calculate the effects of the different factors in the simulation processing.

(Step 6) Based on the step 6), an optimal chromosome is generated.

(Step 7) Selection operation: the roulette wheel approach is selected.

(Step 8) Mutation operation: The probability of mutation is determined by mutation rate.

(Step 9) Offspring population is generated.

(Step 10) If meet the condition then goes to step 11, if not, back to step 2.

(Step 11) The population using the proposed integrated CCGA is generated.

Since the multipath effect is usually occurred in metropolitan area, the random Gaussian noise with mean $\mu = 0$ and variance $\sigma = 1$ is added to time difference of arrival (t_{ij}) obtained previous works by current authors [1, 3]. Here, the distance difference of a pair of radio spectrum monitoring system is obtained as

$$d_{ij} = c \times t_{ij} \times (1.0 + \text{Gaussian Noise} \times \beta) \tag{1}$$

where d_{ij} and t_{ij} denote the distance and time difference between TDOA radio spectrum monitoring station i and j, respectively. The symbol c denotes the propagation speed 3×10^8 m/s. The noise figure β is employed 10% by current simulations. Hence, the non-line of sight scenarios is investigated before the experimental installation.

For conventional TDOA locating approaching, by using a pair of the time difference of arrival, a nonlinear hyperbolic equation is created. Subsequently, two pairs of the time difference of arrival is constructed a set of simultaneous nonlinear hyperbolic equations for three TDOA radio spectrum monitoring station. Finally, by solving the nonlinear hyperbolic equations 2, 3 and 4 simultaneously, the location of transmitter (i.e., referred as interference station) is achieved by using conventional Fang's approaching and Genetic algorithm.

$$d_{AB} = \sqrt{(X_T - X_A)^2 + (Y_T - Y_A)^2} - \sqrt{(X_T - X_B)^2 + (Y_T - Y_B)^2} \tag{2}$$

$$d_{AC} = \sqrt{(X_T - X_A)^2 + (Y_T - Y_A)^2} - \sqrt{(X_T - X_C)^2 + (Y_T - Y_C)^2} \tag{3}$$

$$d_{BC} = \sqrt{(X_T - X_B)^2 + (Y_T - Y_B)^2} - \sqrt{(X_T - X_C)^2 + (Y_T - Y_C)^2} \tag{4}$$

Here, the fitness function is described as

$$f = \sqrt{(F_{AB})^2 + (F_{AC})^2 + (F_{BC})^2} \tag{5}$$

$$F_{AB} = c \times t_{AB} - d_{AB} \tag{6a}$$

$$F_{AC} = c \times t_{AC} - d_{AC} \tag{6b}$$

$$F_{BC} = c \times t_{BC} - d_{BC} \tag{6c}$$

In current study, A, B and C is configured as three monitoring stations, respectively. Hence, F_{ij} denotes the fitness function of monitoring station i and j. In current simulation, the initial population of GA algorithm is set to 20 by using and real-coded method. The roulette method was used to select parent generation of chromosome based on the fitness function of the equation (5). In addition, stopping criterion was employed with the number of 1000 iteration. The number of 10 location estimation is measured while the Gaussian noise with mean $\mu = 0$ and variance $\sigma = 1$ is added to simulate the non-line of sight environment for proposed Integrated CCGA in TDOA location accuracy. Compared to previous Fang approaching [2], the time difference of arrival of obtained general cross-correlation algorithm is added in Gaussian noise shown in Table 1.

Table 1.The simulated time difference of arrival by both proposed integrated CCGA and Gaussian noise (i.e., referred as non-line of sight) environment TDOA radio spectrum monitoring station.

	The time difference of arrival (achieve by proposed integrated CCGA) ± Gaussian noise		
Simulated number index	t_{AB} (us)	t_{AC} (us)	t_{BC} (us)
1	15.11+ 0.1253	21.85 - 0.4326	36.95 - 1.6656
2	15.11 + 1.1909	21.85 + 0.287	36.95 - 1.1465
3	15.11 + 0.3273	21.85 + 1.1892	36.95 - 0.0376
4	15.11 + 0.7258	21.85 + 0.1746	36.95 - 0.1867
5	15.11 - 0.1364	21.85 - 0.5883	36.95 + 2.1832
6	15.11 + 0.0593	21.85 + 0.1139	36.95 + 1.0668
7	15.11 + 0.2944	21.85 - 0.0956	36.95 - 0.8323
8	15.11 + 1.6236	21.85 - 1.3362	36.95 + 0.7143
9	15.11 + 1.2540	21.85 - 0.6918	36.95 + 0.8580
10	15.11 + 0.5711	21.85 - 1.5937	36.95 - 1.4410

3. THE SIMULATION OF VARIOUS LOCATION SOLUTIONS IN NLOS ENVIRONMENT

For TDOA radio spectrum monitoring system in theory, the location accuracy of inside coverage area is better than those of outside coverage area. Here two kinds of geographical are simulated to investigate the location performance as follows.

As shown in Fig. 1 for the inside coverage area simulation of TDOA radio spectrum monitoring system, A, B and C monitoring stations are installed on two dimension (2D) geographical position of (0,0), (10,0) and (10,10), respectively. Initial position of transmitter (referred as interference station) is located on (8,6) coordinate point. Here, the ten simulation results of location estimation with Fang’s approaching and Genetic algorithm are shown in Table 2.

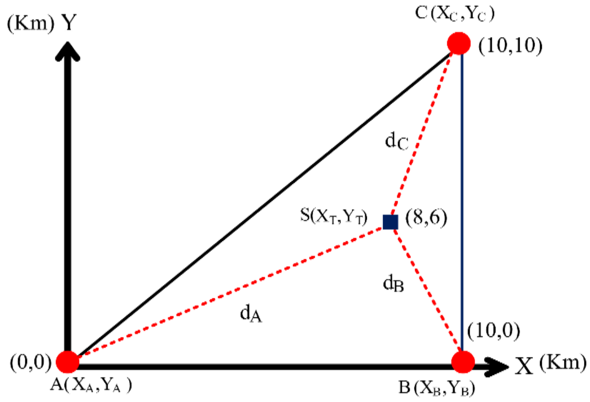

Fig. 1. The inside coverage area simulation of TDOA monitoring station A, B and C on geographical position of (0,0), (10,0) and (10,10) coordinate point, respectively. Initial position of transmitter is located on (8,6) coordinate point.

Table 2.The location estimation analysis by using Fang's approaching and genetic algorithm under Gaussian noise (i.e., referred as non-line of sight) consideration for TDOA inside coverage area.

inside coverage area	Location estimation S(X,Y) of Fang's approaching under Gaussian noise (i.e., referred as non-line of sight) consideration			Location estimation S(X,Y) of genetic algorithm under Gaussian noise (i.e., referred as non-line of sight) consideration		
Simulated number index	X Coordinate	Y Coordinate	Root mean square error (RMSE)	X Coordinate	Y Coordinate	Root mean square error (RMSE)
1	7.603	5.900	0.409716	7.602	5.897	0.411112
2	7.800	5.965	0.203095	7.798	5.960	0.205922
3	8.215	5.927	0.227424	8.214	5.926	0.226433
4	7.974	6.021	0.033307	7.973	6.020	0.033601
5	8.330	6.234	0.404107	8.318	6.222	0.387825
6	8.230	6.087	0.246089	8.228	6.086	0.24368
7	7.814	5.957	0.190581	7.814	5.955	0.191366
8	7.821	6.289	0.340155	7.82	6.287	0.338776
9	7.988	6.219	0.219067	7.987	6.217	0.217389
10	7.409	6.048	0.593301	7.409	6.047	0.592866

The outside coverage area simulation of TDOA radio spectrum monitoring system is shown in the Fig. 2. Similarly, A, B and C monitoring stations are installed on two dimension (2D) geographical position of (0,0), (10,0) and (10,10), respectively. Initial position of transmitter (referred as interference station) is located on (12,9). Here, the ten simulation results of location estimation with Fang's approaching and Genetic algorithm are shown in Table 3.

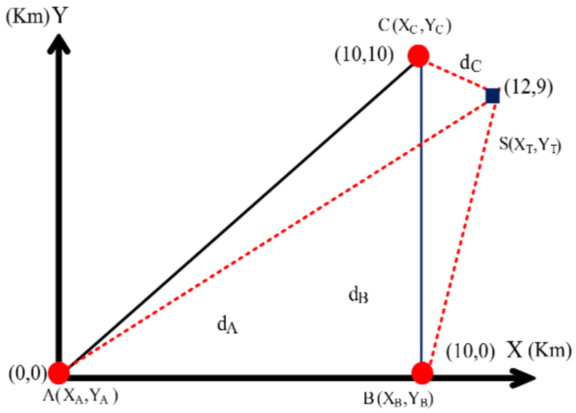

Fig. 2. The outside coverage area simulation of TDOA monitoring stations A, B and C on geographical position of (0,0), (10,0) and (10,10) coordinate point, respectively. Initial position of transmitter is located on (12,9) coordinate point.

Table 3.The location estimation analysis by using Fang's approaching and genetic algorithm under Gaussian noise (i.e., referred as non-line of sight) consideration for TDOA outside coverage area.

outside coverage area	Location estimation S(X,Y) of Fang's approaching under Gaussian noise (i.e., referred as non-line of sight) consideration			Location estimation S(X,Y) of genetic algorithm under Gaussian noise (i.e., referred as non-line of sight) consideration		
Simulated number index	X Coordinate	Y Coordinate	Root mean square error (RMSE)	X Coordinate	Y Coordinate	Root mean square error (RMSE)
1	10.338	8.388	1.770584	11.171	8.524	0.955938
2	11.356	9.366	0.740514	11.555	8.830	0.476366
3	13.455	9.936	1.729920	12.498	8.796	0.538164
4	11.841	9.164	0.228413	11.916	9.084	0.118794
5	10.931	8.125	1.381521	12.544	9.901	1.052491
6	14.454	12.432	4.219290	12.436	9.380	0.578356
7	11.091	8.634	0.979972	11.611	8.796	0.439246
8	11.504	9.771	0.917371	11.422	10.007	1.161091
9	12.713	10.550	1.706071	11.825	9.81	0.828689
10	9.773	8.556	2.270613	10.652	8.996	1.348006

Analyzing and comparison for various Fang approaching and proposed genetic algorithms, the root mean square error (RMSE) is shown in Table 2 and 3, respectively. In current simulation shown in Table 2, the location accuracy of proposed CCGA is approximately same as those of the conventional Fang approaching while transmitter (i.e, is referred as interference station) is located on the geographical position of inside of TDOA coverage area. Furthermore, as shown in Table 3, the location accuracy of proposed CCGA is significantly better than those of the conventional Fang approaching while transmitter is located on the geographical position of outside of TDOA coverage area.

4. CONCLUSION

By adding the Gaussian noise with mean $\mu = 0$ and variance $\sigma = 1$ for multi-path effect, the proposed integrated cross-correlation and genetic algorithm (integrated CCGA) scheme for previous work by current authors was investigated and evaluated in NLOS environment. In current simulated processing before the practical experiment in the future work, by solving nonlinear hyperbolic equation with the proposed CCGA scheme in NLOS environment, the multiple simultaneous solutions is obtained for fix and stable locating solution. Furthermore, the proposed CCGA scheme is easily to flexibly adjust the parameter setting in various environments to select the optimal positioning solution. However, by solving conventional FANG approaching, the location may encounter unable to find the optimum solution (i.e., only intersect at one coordinate point). Especially, the location error is significantly increased while the transmitter is far away from the outside coverage area of TDOA radio spectrum monitoring station. Hence, Even though in NLOS environment, the simulation results show that the proposed scheme is easily to identify, locate, and remove radio interference resulting from low transmission power, burst and weak signals, or metropolitan.

5. REFERENCES

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