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Performance Evaluation of Location Estimation System Using a Non Fixed Single Receiver

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ABSTRACT

General location aware systems are only applied to indoor and outdoor environments using more than three transmitters to estimate a fixed object location. Those kinds of systems have environmental restrictions that require an already established infrastructure. To solve this problem, an Object Location Estimation (OLE) algorithm based on PTP (Point To Point) communication has been *proposed. However, the problem with this method is that deduction of performance parameters is not enough and location estimation is very difficult because of unknown restriction conditions. From experimental tests in this research, we determined that the performance parameters for restriction conditions are a maximum transmission distance of CSS communication and an optimum moving distance interval between personal locations. In this paper, a system applied OLE algorithm based on PTP communication is implemented using a CSS (Chirp Spread Spectrum) communication module. A maximum transmission distance for CSS communication and an optimum moving distance interval between personal locations are then deducted and studied to estimate a fixed object location for generalization.*

Key words*: Location Estimation, PTP, CSS, SDS-TWR.*

1. INTRODUCTION

Nowadays location estimation and navigation technologies are useful for a daily life. Especially, to estimate and find a location of the fixed object such as a car, in large size indoor and outdoor environments such as parking lots of mall, are necessary. The location estimation and navigation technologies may be classed into indoor technology and outdoor technology.

GPS (Global Positioning System) is used for wireless positioning technology outdoors [1]. Wireless communication technologies such as WLAN (Wireless Local Area Network), UWB (Ultra Wide Band), ZigBee, CSS (Chirp Spread Spectrum) and etc. are used for wireless positioning technology indoors[2]-[5]. Studies for location recognition algorithms, applied in indoor and outdoor environments, have been done. Those algorithms are TOA (Time Of Arrival), RSSI (Received Signal Strength Intensity), AOA (Angle Of Arrival) and etc. [6-7]. To estimate the location of an object, it is general to apply a triangulation method on an infrastructure composed of wireless modules and servers. But there is a problem that above method system can be only applied when an especial infrastructure is established.

To solve this problem, an object location estimation method using PTP communication has been proposed [8]-[10]. But there is a problem that deduction of performance parameters for the location estimation is not enough.

In this paper, our goal is to study OLE algorithm and to propose the condition to generalize the algorithm in wireless communication environment. To achieve this, we choose CSS communication as a wireless communication environment.

Then the location estimation system based on PTP communication is implemented. A maximum transmission distance of CSS communication and an optimum moving distance intervals between personal locations in indoor and outdoor environments are deducted by experimental results.

The remaining sections are structured as follows. Section 2 provides an overview of the related works in the area of CSS technology. Section 3 describes the main structure and implementation of the system. In Section 4 experiment environments are described. Then experiment results are

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analyzed in Section 5. Finally, we present our conclusions and future work in Section 6.

2. RELATED WORKS

2.1 Ranging by SDS-TWR Algorithm with CSS Technology

SDS-TWR (Symmetrical Double-Sided Two Way Ranging) algorithm is an advanced algorithm compared with the TWR algorithm. It is based on clock synchronization mechanism. Fig. 1 shows wireless sensor node infrastructure applied to SDS-TWR algorithm. The infrastructure consists of a server and sensor nodes.

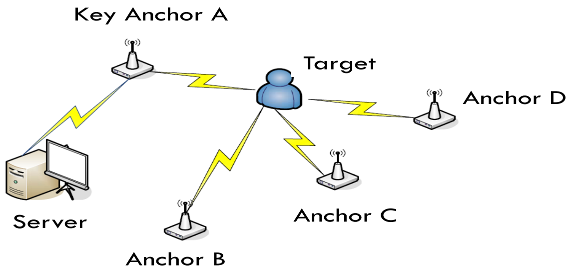
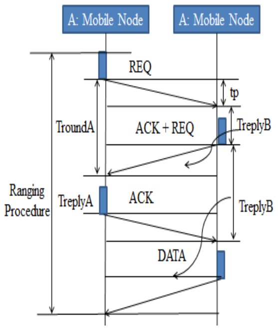
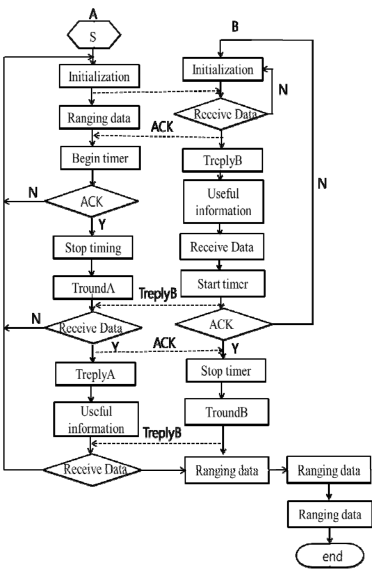


Fig. 1. Wireless sensor node localization model

Fig. 2 shows a working procedure and a flow chart of the SDS-TWR algorithm



a. Working procedure of SDS-TWR



b. Flowchart of SDS-TWR

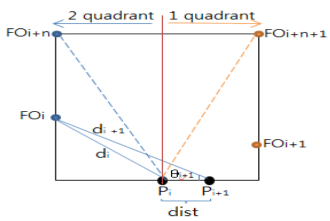
Fig. 2. Working procedure and flow chart of the SDS-TWR

As shown in Fig. 2, SDS-TWR algorithm works as follows: Firstly, the anchor node A sends the ranging data to the un-known node B, and then starts a timer. When node B receives the ranging data from node A, node B sends ACK (acknowledgment frame) to node A. At this point, node B's response time is recorded as TreplyB. When node A receives the ACK which is sent by the node B, node A stops timer, and the time of node A is recorded as TreplyA. Then, the node B sends the ranging data to the node A, node B starts a timer. When node A receives the ranging data from node B, node A sends acknowledgment frame to node B. At this point, node B's response time is recorded as TreplyB. When node B receives the ACK which is sent by the node A, node B stops timer, and the time of node B is recorded as TroundB. Tp, the propagation delay time of the ranging signal in the air, is established. According to the procedure of SDS-TWR, it can be derived by the following Eq. (1) [7].

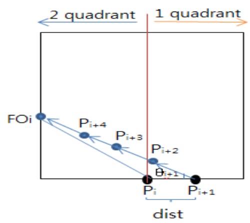
$$T_p = \frac{1}{4}\left(T_{roundA} - T_{replyB} + T_{roundB} - T_{replyA}\right) \qquad (1)$$

2.2 Object Location Estimation (OLE) algorithm

OLE algorithm using PTP communication is shown in Fig. 3.



a. Initial setup state



b. Progress state

Fig. 3. Object location estimation model at two points

The OLE algorithm has two states:

1) Initial setup state (Fig. 3a)

A distance (d_i) between a first location (P_i) of a person and a fixed object of i^{th} (FO_i) is measured by Eq. (2). C is a transmission velocity of radio wave. After the person moves to second location (P_{i+1}) by a distance interval (dist is a distance between Pi and P_{i+1}), a distance (d_{i+1}) is measured as shown in Fig. 3a. If it is $d_i >= d_{i+1}$, the fixed object is located in 1 quadrant or 2 quadrant. Θ_{i+1}, an angle of the received signal at $P_{i+1,}$ is calculated using d_i and d_{i+1} shown as Eq. (3):

$$\text{Distance} = \text{Tp x C} \qquad (\text{where, C=3 x}10^{8}\text{ m/s}) \qquad (2)$$

$$\theta_{i+1} = \cos^{-1}\frac{(d_i^2 - dist^2 - d_{i+1}^2)}{2\, d_{i+1}\, dist}, \qquad i = 0, 1, 2\ \ldots \qquad (3)$$

2) Progress state (Fig. 3b)

After state 1 is perfomed, a person moves to third location (P_{i+2}) toward target along Θ_{i+1} by dist. Also, a distance (d_{i+2}) between FO_i and P_{i+2} is checked same as $d_{i+2} < d_{i+1}$. Then state 2 is continuously doing until estimating the fixed object location.

3. STRUCTURE AND IMPLEMENTATION

The structure of the location system applied OLE algorithm for a fixed object is shown in Fig. 4.

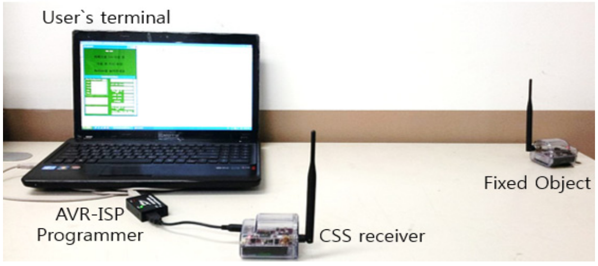


Fig. 4. Structure of location estimation system

In here, a person has user`s terminal. It consists of a notebook, AVR-ISP (AVR In-System Programming) programmer and a CSS receiver. OLE algorithm is run in notebook GUI. The GUI environment is made by Visual C++ in MS 2008.

Raw data (d_i) is derived from the fixed object to CSS receiver in CSS communication. Then the CSS receiver sends raw data to the notebook using AVR-ISP programmer. It converts UART communication to RS-232 communication. Then a measured distance is shown in GUI environment. An angle (Θ_{i+1}) is calculated by the OLE algorithm implemented in GUI. It is shown in GUI environment.

4. EXPERIMENT ENVIRONMENT

In here, experiments` purpose is to derive a maximum transmission distance and an optimum moving distance interval in CSS communication.

4.1 Maximum transmission distance measurement

This experiment purpose is to derive a maximum transmission distance in CSS communication. The experiment is performed in outdoor environment (13.99m X 70m X 1m) as shown in Fig. 5.

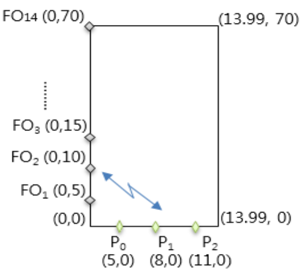


Fig. 5. Outdoor experiment environment to derive a maximum transmission distance

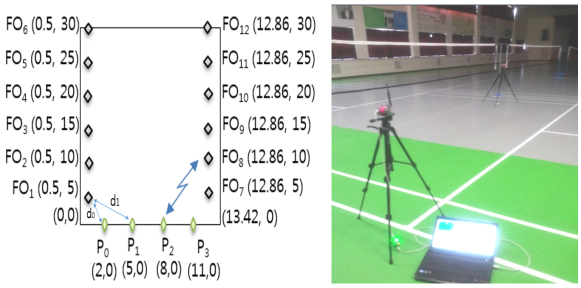
There are 14 fixed objects(FO_n, where n=1, 2, ⋯, 14) which are located by 5m interval each other. A distance from personal locations (P_0, P_1 or P_2) to target (FO_n) is measured in CSS communication by Eq. (1)-(2). Measurement trial times are 21 per a distance.

4.2 Experiment to derive an optimum distance interval on CSS communication

Below experiments purpose is to find an optimum moving distance interval from 3m, 6m and 9m when the OLE algorithm is applied in indoor and outdoor environments.

4.2.1 Indoor environment

The experiment is performed in indoor environment (13.42m X 30m X 1m) as shown in Fig. 6.



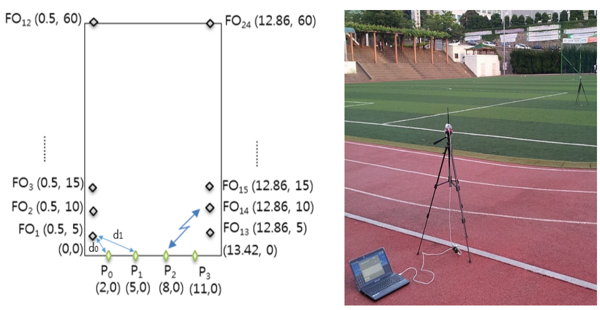
a. Set 12 fixed objects b. Real experiment environment

Fig. 6. Indoor experiment environment

CSS communication can be performed well when it is located at 1m toward z coordinate. So CSS receiver and the fixed object are set at 1m from ground. Fig. 6a shows 12 fixed objects that are set by 5m interval. Thus first start location is P_0, P_1, P_2 and P_3 which are location points moved by 0m, 3m, 6m and 9m from P_0 respectively. We can decide a quadrant decision by a relation of d_0 and d_1. If $d_0 >= d_1$, a fixed object location is supposed in quadrant 1. Otherwise a fixed object is located in quadrant 2. d0 (between P_0 and FO_1) is measured by 10 times and calculated by average value. It is discarded the calculated average distance when a distance is measured by -1. The average distance is shown in user`s terminal GUI environment. Then user moves P_1 and measure a distance (d_1) between P_1 and FO_1. An average distance of d_1 is measured by same method as an average distance of d_0. The d_0 and d_1 is used to calculate an angle (Θ_{i+1}) at P_1. Other case (P_2 and P_3) is performed same as above progresses.

4.2.2 Outdoor environment

The experiment is performed in outdoor environment (13.42m X 60m X 1m) as shown in Fig. 7.



a. 24 fixed object coordinates b. Real experiment environment

Fig. 7. Outdoor experiment environment

Fig. 7a shows 24 fixed object coordinates that are set by 5m interval toward to z axis. First start location is P_0, P_1, P_2 and P_3 which are location points moved by 0m, 3m, 6m and 9m from P_0. A distance from P_0, P_1, P_2 or P_3 to target is measured by the same methodology as indoor environment.

5. EXPERIMENT RESULT

5.1 Maximum transmission distance measurement

Table 1 shows a probability for each distance to measure (Prob_d_meas) between real distances (Real_d) and average measured distances (A_meas_d) from P_0 to FO_n when a distance was measured by 21 times (Real_meas_time).

Table 1. Probability for each distance to measure

$P_0\_FO_n$	Real_d	A_meas_d	Real_meas_time	Exp_meas_time	Prob_d_meas
$P_0\_FO_1$	5	7.47	21	21	100
$P_0\_FO_2$	10	9.76	21	18	85.71
$P_0\_FO_3$	15	13.88	21	18	85.71
$P_0\_FO_4$	20	-1	21	21	0
$P_0\_FO_5$	25	22.77	21	18	85.71
$P_0\_FO_6$	30	30.12	21	20	95.23
$P_0\_FO_7$	35	36.73	21	21	100
$P_0\_FO_8$	40	37.79	21	19	90.47
$P_0\_FO_9$	45	46.61	21	16	76.19
$P_0\_FO_{10}$	50	51.78	21	20	95.23
$P_0\_FO_{11}$	55	56.83	21	15	71.427
$P_0\_FO_{12}$	60	61	21	3	14.28
$P_0\_FO_{13}$	65	67.34	21	5	23.80
$P_0\_FO_{14}$	70	71.95	21	2	9.523

Experiment measured time (Exp_meas_time) was expressed for measured distance time. We considered that the measured distance could be measured when Meas_prob_d was over 60%. In this case, for $P_0\_FO_n$, Exp_meas_time and Meas_prob_d were shown that a maximum transmission distance measurement of CSS communication on PTP was measured by average 88.57% when the safety measured distance was within 55m except for $P_0\_FO_4$ (the real distance was 20m). When the probability of a measured distance was over 60%, a distance couldn`t be measured because of Pro_d_meas.

Fig. 8 shows about all case (P_0_FOn, $P_1\_FO_n$ and $P_2\_FO_n$).

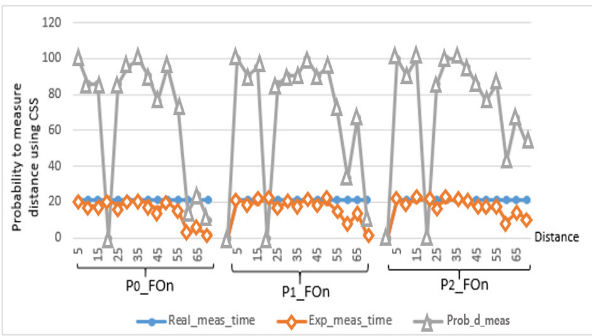


Fig. 8. A probability of distances from each $P_0\_FO_n$, P_1_FOn and $P_2\_FO_n$

For $P_1\_FO_n$, an average of maximum transmission distance measurement of CSS communication on PTP was 90.95% when a probability of measured distance was within 55m except for $P_1\_FO_4$ (the real distance was 20m). When the probability of a measured distance was over 60%, distances couldn`t be measured about 60m and 70m. But $P_1\_FO_{13}$ was measured by 66.66% when the real distance is 65m.

For $P_2\_FO_n$, an average of maximum transmission distance measurement of CSS communication on PTP is 91.9% when the real distance was within 55m except for $P_2\_FO_4$ (the real distance was 20m). When the real distance was over 60, a distance couldn`t be measured about 60m and 70m. But $P_2\_FO_{13}$ was measured by 66.66% when the real distance was 65m.

Real distance was compared with absolute average errors in Fig. 9 for $P_0\_FO_n$, $P_1\_FO_n$ and $P_2\_FO_n$.

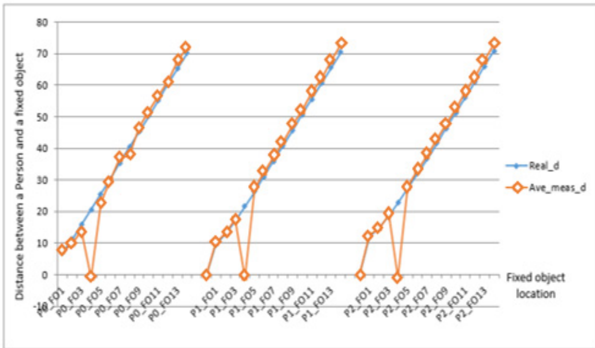


Fig. 9. Absolute distance errors for $P_0\_FO_n$, $P_1\_FO_n$ and $P_2\_FO_n$

When the real distance was 20m for all case, a distance couldn't be measured same as the measured distance probability. So we considered calculating absolute average distance error except for $P_0\_FO_4$, $P_1\_FO_4$ and $P_2\_FO_4$. Absolute average distance error of $P_0\_FO_n$ was 0.82m. Absolute average distance error of $P_1\_FO_n$ was 0.94m. Absolute average distance error of $P_2\_FO_n$ was 0.71m. Therefore absolute average distance error of all case was 0.82m. The safety maximum transmission distance was 55m. But we considered a maximum transmission distance was 60m because maximum transmission distances of P_1 and P_2 were more than 60% criteria.

5.2 Experiment to derive an optimum moving distance interval on CSS distance

5.2.1 Indoor

Table 2 shows that absolute average distance errors (a_d_err) at P_0 and P_1 were 1.88m and 1.9m when the moving distance interval between P_0 and P_1 was 3m.

Table 2. Moving Distance interval is 3m in indoor

Fixed Object	P0 a_d_err	P1 a_d_err	Real Θ1	Meas Θ1	Θ1 err	Real Quad	Meas Quad
FO1	0.02	1.28	132.05	110.81	21.2	2	2
FO2	-2.7	-2.27	114.28	114.98	-0.69	2	2
FO3	1.8	0.15	106.75	142.11	-35.4	2	2
FO4	-0.3	-0.5	102.73	106.19	-3.46	2	2
FO5	-1.7	1.41	100.25	94.22	6.04	2	2
FO6	1.02	2.93	98.58	59.96	38.6	2	1
FO7	1.36	1.39	32.47	31.332	1.15	1	1
FO8	3.26	-0.96	51.85	141.45	-89.6	1	2
FO9	6	5.09	62.37	84.03	21.7	1	1
FO10	1.62	4.61	68.57	73.30	-4.72	1	1
FO11	1.9	2.02	72.58	70.36	2.22	1	1
FO12	1.36	0.12	75.35	99.38	-24	1	2

Absolute average angle error was 16.7 degree for all case. Quadrants for FO_8 and FO_{12} in table 2 were not same as real quadrant (Real Quad) 1 because absolute distance error was made by multi path loss. Other quadrants were same as real quadrants.

When the moving distance interval was 6m, absolute average distance errors were 1.77m and 1.81m at P_0 and P_2, respectively. Absolute average angle error was 14.4 degree. Quadrant of FO_1 was different with real quadrant 2. Other quadrants were same as real quadrants.

When the moving distance interval was 9m, absolute average distance errors were 1.75m and 2.2m at P_0 and P_3, respectively. Absolute average angle error was 8.56 degree. Quadrant of FO_5 was different with real quadrant 2. Other quadrants were same as real quadrants. For all case, absolute average distance errors were 1.8m at P_0 and 1.97m at P_1, P_2 and P3, respectively. Absolute average angle error was 13.2 degree.

5.2.2 Outdoor

Table 3 shows that absolute average distance errors were 3.06m and 3.13m at P_0 and P_1, respectively when the moving distance interval between P_0 and P_1 was 3m.

Table 3. Moving interval is 3m in outdoor

Fixed Object	P0 a_d_err	P1 a_d_err	Real Θ1	Meas Θ1	Θ err	Real Quad	Meas Quad
FO1	-1.202	0.009	132.054	108.6319	23.4	2	2
FO2	-1.055	-0.619	114.285	105.444	8.84	2	2
FO3	0.736	0.994	106.753	102.145	4.61	2	2
FO4	11.411	7.603	102.732	145.5336	-42.8	2	2
FO5	13.998	14.679	100.254	91.7147	8.54	2	1
FO6	-1.531	-1.445	98.58	96.7743	1.81	2	2
FO7	9.496	9.359	97.375	100.8277	-3.45	2	2
FO8	10.854	10.954	96.467	95.3042	1.16	2	2
FO9	3.108	7.948	95.759	x	x	2	x
FO10	19.062	13.871	95.191	x	x	2	x
FO11	20.811	38.116	94.336	x	x	2	x
FO12	35.438	35.528	32.478	94.6184	-0.28	2	2
FO13	-0.133	-1.36	32.478	68.7973	-36.3	1	1
FO14	-1.519	-2.496	51.858	74.3833	-22.5	1	1
FO15	1.884	1.992	62.579	80.2943	-17.9	1	1
FO16	7.981	7.318	68.579	84.2338	-15.7	1	1
FO17	7.042	6.87	72.583	77.1889	-4.61	1	1
FO18	-1.709	-1.537	75.356	71.6765	3.68	1	1
FO19	3.059	2.318	77.382	91.9121	-14.5	1	1
FO20	2.679	2.321	78.923	85.9797	-7.06	1	1
FO21	3.388	2.728	80.132	92.9565	-12.8	1	2
FO22	8.964	8.575	81.107	88.9443	-7.84	1	1
FO23	19.096	20.769	81.908	45.1498	36.8	1	1
FO24	23.166	22.85	82.578	89.4689	-6.89	1	1

Absolute average angle error was 13.4 degree. Quadrants for FO_8, FO_9, FO_{12} and FO_{21} were not same as correspondent real quadrants because absolute distance errors were made by multi path loss. Other quadrants were same as correspondent real quadrants.

When the moving distance interval was 6m, absolute average distance errors were 3.74m and 3.74m at P_0 and P_2, respectively. Absolute average angle error was 26 degree. Quadrants for FO_1, FO_4, FO_9, FO_{11}, FO_{12}, FO_{21}, FO_{22} and FO_{23} are different with correspondent correct quadrants. Other quadrants were same as real quadrants.

When the moving distance interval was 9m, absolute average distance errors were 2.16m and 2.9m at P_0 and P_3, respectively. Absolute average angle error was 15.5 degree. Quadrants for FO_6 and FO_8 were different with correspondent correct quadrant. Other quadrants were same as real quadrants. For all case, absolute average distance errors were 2.99m at P_0 and 3.26m at P_1, P_2, and P_3. Absolute average angle error was 18.3 degree.

The quadrant was correctly checked by 83.33% when the moving distance interval in indoor and outdoor environments was 3m. The quadrant was correctly checked by 91.6% for indoor environment and 66.66% for outdoor environment when the moving distance interval in indoor and outdoor environments was 6m.The quadrant was checked correctly by 91.6% when the moving distance interval in indoor and outdoor environments was 9m.

6. CONCLUSION AND FUTURE WORK

OLE algorithm based on PTP communication was studied indoors (10m X 16m X 1m) before. This paper was studied to generalize the OLE algorithm. For it, OLE algorithm was applied and implemented. Therefore, the maximum transmission distance and the optimum moving distance interval were deducted and used to estimate a fixed object location.

The maximum transmission distance was 55m at P_0 by experiment results. But we considered maximum transmission distance was 60m for finding the optimum moving distance interval because maximum transmission distances of P_1 and P_2 were more than 60% criteria. Absolute average distance error of all case was 0.82m. The distance couldn`t be measured for P_0_FO_4, P_1_FO_4, and P_2_FO_4 when the moving distance interval was 20m.

The quadrant was checked correctly by 83.33% and 91.6% when the moving distance interval in indoor and outdoor environments was 3m and 9m respectively. So optimum moving distances was 3m and 9m in indoor and outdoor environments respectively. When the OLE algorithm was verified in indoor (13.42m X 30m X 1m) for all case, absolute average distance errors were 1.8m at P0 and 1.97m about P_1, P_2 and P_3. Absolute average angle error was 13.2 degree. When OLE algorithm was verified in outdoor (13.42m X 60m X 1m) for all case, absolute average distance errors were 2.99m at P_0 and 3.26m at P_1, P_2 and P_3. Absolute average angle error was 18.3 degree.

In conclusion, OLE algorithm using CSS communication could be possible to estimate a fixed object location when the fixed object is located in indoor (30m) and outdoor (60m) environments. However, there was multi path loss. Future work is that OLE algorithm should be studied when a moving distance interval can be measured automatically and is not constant. Also, a compensation algorithm for a distance error should be studied.

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REFERENCES

[1] Robin Wentao Ouyang, Albert Kai-Sun Wong, and Kam Tim Woo, "GPS Localization Accuracy Improvement by Fusing Terrestrial TOA Measurements," Proceedings of ICC , 2010, pp. 1-5.

[2] Arsham Farshad, Jiwei Li, Mahesh K. Marina, and Francisco J. Garcia, "A Microscopic Look at WiFi Fingerprinting for Indoor Mobile Phone Localization in Diverse Environments," Proceedings of IPIN, 2013, pp. 28-31.

[3] Mare Srbinovska, Cvetan Gavrovski, and Vladimir Dimcev, "Localization Estimation System Using Measurement of RSSI Based on Zigbee Standard," Proceedings of Electronics, 2008, pp. 24-26.

[4] Yoon-Seok Nam, "Location Estimation of Mobile Devices in CSS WPANs," International Journal of Multimedia and Ubiquitous Engineering, vol. 9, no. 3, 2014, pp. 31-40.

[5] Junyang Shen and Andreas F. Molisch, "Passive Location Estimation Using TOA Measurements," Proceedings of ICUWB, 2011, pp. 253-527.

[6] Hong Tang, Yongwan Park, and Tianshuang Qiu, "A TOA-AOA-Based NLOS ErrorMitigationMethod for Location Estimation," EURASIP Journal on Advances in Signal Processing, vol. 2008, no. 86, 2008.

[7] Liu Wei, Zou Jian, Wang Chunzhi, and Xu Hui, "Kalman Filter Localization Algorithm Based on SDS-TWR Ranging," vol. 11, no. 3, 2013, pp. 1436-1448.

[8] E. Myagmar and S. R. Kwon, "An Angular Calculation based TOA Algoritm for Location Estimation by Point to Point Communication," Journal of KIISE: Computer System and Theory, vol. 38, no. 2, 2011, pp. 94-101.

[9] E. Myagmar and S. R. Kwon, "Location Recognition Method based on PTP Communication", Journal of the Korea Contents Association, vol. 14, no. 3, 2014, pp. 33-39.

[10] S. H. Lim, E. Y. Woo, J. Y. Choi, H. S. Kong, E. Myagmar, and S. R. Kwon, "Location Guiding System by PTP Communication based on CSS," Proceedings of the Korea Multimedia Society Fall Conference, vol. 16, no. 2, 2013, pp. 113-115.

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