재난 복구시 신속 배치 가능한 응급통신시스템에서 긴급구조원의 실내위치측정

Indoor Position Estimation of First Responders for Rapidly Deployable Emergency Communication Systems in Disaster Recovery

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ABSTRACT

This paper presents the incorporation of still-alive access points (SAPs) and helper access points (HAPs) that can be utilized as anchor nodes for position estimation of a First Responders (FRs) for rapidly deployable Emergency Communication Systems (ECS) in disaster recovery. In addition, the localization environment has is formulated and initially examines the use of a distributed Gauss-Newton algorithm (GNA) as optimization technizue. A simulation has been conducted and compared with the commonly used trilateration approach in position estimation.

1. Introduction

In the occurrence of a natural disaster, accidents or terrorism, stable communication plays a vital role in emergency-related activities. However, communication infrastructure such as cellular network may have been destroyed or disrupted and unable to support crucial activities. A rapidly deployable emergency communication system like that of [1] can be utilized to make important emergency activities possible.

One of the crucial activity of FRs in the event of a disaster is rescue and recovery missions. It entails getting inside buildings, tunnels (subways) and other indoor establishments with the high expectancy of rubbles and obstruction caused by the disaster. A terrain map, building or floor plan integrated into an application that transmits FR's location data to the emergency operations center (EOC) would be a significant tool. However, with the loss of communication infrastructures, this becomes a problem. Moreover, current map applications often rely on GPS and with the inaccuracy of GPS in indoor settings an in-situ localization technique is seen as a necessity. In lieu of GPS, a common solution that has been proposed in the literature is the use of RSSI (received signal strength indicator) [3] that can be captured from and by mobile devices.

This paper explores the utilization of available or still-alive-access points (SAPs) as anchor nodes for FR location approximation in an incident area. A well-formed network formulation and position optimization using Gaussian Newton Algorithm (GNA) has been implemented. The proposed study considers a distributed localization process since a particular FR node can become a reliable anchor node once it determines its own process.

2. Proposed Work

We characterized the network as follows; consider an FR i that get inside a particular indoor area with the estimated position Pdi and its exact position Pi. If an FR i can establish a connection with a SAP or HAP j with known location, the distance dij between the two node can be estimated through the RSSI measurement as dmij. We can then obtain the likelihood function,

$$L_{rij}(P_i) = P(d_{m_{ij}}|P_i, P_j) \quad (1)$$

where Pj is either a SAP or HAP with known location. In most cases, the RSSI measured distance is typically assumed as Gaussian distributed, therefore, for an unkown FR i and anchor node (SAP/HAP/FR) j, the likelihood function Pi is,

$$P(d_{mij}|P_i, P_j) = \quad (2)$$
$$\frac{1}{\sqrt{2\pi(d_{mij}r)}} \exp\left(-\frac{(\delta(P_i, P_j) - d_{mij})^2}{2(d_{mi}r)^2}\right)$$

where is the distance between location . Furthermore, as Pdi is assume bivariate normal distributed with the real position Pi, the initial position Pi can be obtained as a probability function

$$L_{di}(P_i) = \frac{1}{2\pi\sigma_x\sigma_y} \quad (3)$$
$$\exp\left(-\frac{1}{2}\frac{(x_i - x_{di})^2}{\sigma_x^2} + \frac{(y_i - y_{di})^2}{\sigma_y^2}\right)$$

where and are approximated and e is the error factor.

When all nearby SAPs and HAPs have communicated represented by Ji and all FR position and RSSI ranging measurements are independent of each other, the overall likelihood function is obtained by multiplying all the likelihood functions for the unknown FR i. Thus,

$$\overline{L}_i(P_i) = \frac{1}{2\pi\sigma_x\sigma_y} \quad (4)$$

$$\exp\left(-\frac{1}{2}\frac{(x_i - x_{di})^2}{\sigma_x^2} + \frac{(y_i - y_{di})^2}{\sigma_y^2}\right)$$

$$\cdot\prod_{j\in J_i}\left(\frac{1}{\sqrt{2\pi(d_{mij}r)}}\exp\left(-\frac{(\delta(P_i,P_j)-d_{mij})^2}{2(d_{mij}r)^2}\right)\right.$$

Taking the natural logarithm of Li(Pi) results in

$$\ln L_i(P_i) = \alpha - S(P_i) \quad (5)$$

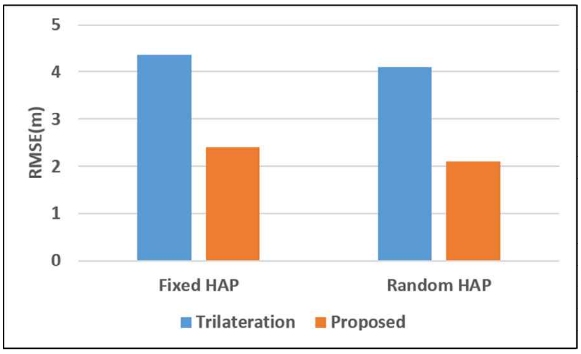
where $\alpha = -\ln 2\pi\sigma_x\sigma_y - \sum_{j\in J_i}\ln\sqrt{2\pi d_{ij}r}$ and the function

$$S(P_i) = \frac{(x_i - x_{di})^2}{\sigma_x^2} + \frac{(y_i - y_{di})^2}{\sigma_y^2} + \sum_{j\in J_i}\frac{(\sigma(P_i,P_j) - d_{mij})^2}{2(d_{mij}r)^2}$$

Furthermore, to find the position that maximizes, function should be minimized and we use Gauss-Newton algorithm (GNA) as implemented in [2].

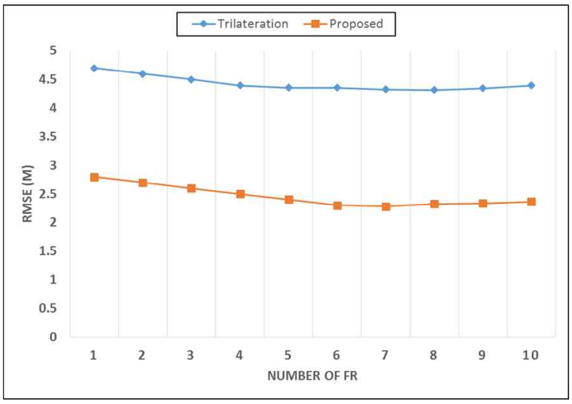
3. Results and Discussion

A simulation experiment using Matlab (R2017a) was performed to be able to evaluate the effectiveness of the proposed approach and simulation settings like fixed/random locations of SAPs, HAPs, and increasing number of FRs were incorporated to analyze how these affects the proposed approach. For simple comparison on indoor localization, the proposed approach was compared with location estimation using trilateration and root mean square error (RMSE) of the actual distances and estimated distances are calculated.



▶▶ Figure 1. Proposed word and trilateration comparison of RMSE when HAP location is Random/Fixed.

It has been observed in several studies that the use of GNA is mostly applicable for sparse network [3]. This characteristic should also be true to First Responder Systems during disaster scenarios. Figures 1 depicts the RMSE of the proposed approached in comparison with trilateration distance approximation. It can be seen that the proposed approach attains approximately 2m distance error that would be acceptable for indoor localization. The random placement of SAPs in the proposed approach has little effect on the RMSE. and a change in RMSE as FR is increasing is seen in Figure 2.



▶▶ Figure 2. RMSE of trilateration and proposed work as First Responders is increasing.

4. Conclusion

The proposed work formulated the disaster environment as a sparse network and explores the use of Gaussian Newton Algorithm to solve the nonlinear least-square problem of localization by only local communication between neighboring nodes. Further, the algorithm is robust and scalable as nodes do not require any knowledge about the network topology or size. The results show acceptable RMSE that prove that GNA is suitable to use to optimize the location approximation.

5. Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (2016R1A2B4013002).

▌References ▌

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