Poster Abstract: Anchor Placement Optimization for Area-Based Localization Using Tabu Search Algorithm

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Abstract

Recently interest in indoor localization due to demands for location-based services has increased. Diverse techniques have been described in the literature to improve indoor localization services supplied to consumers, but their accuracy is notably affected by the count and location of anchors. This work describes an approach to finding an optimum placement of the anchors' locations in the half-symmetric lense (HSL) which is one of the area-based localization techniques. Results indicate that our approach gains nearly the same quality as comparing approaches, but it improves the time of execution for three and four anchors by nearly 2 and 20 times, respectively.

1 Introduction and Motivation

Nowadays, indoor consumer localization systems are becoming more popular in the market. Most prominent wireless Communication technologies, including RFID, Bluetooth, Wi-Fi, and Ultra-Wide-Band (UWB), are also effective localization technologies with an accuracy of one or two centimeters to a few meters [2]. In area-based localization, instead of determining a single-point position, the goal is to find a zone of minimum size in which a node is positioned. Area-based approaches provide a more realistic depiction of position uncertainty by linking it to a geometric form region known as the dwelling area. Based on the geometry of the residential area, area-based localization methods may be categorized as circle-based [7], symmetric/half-symmetric lens-based area localization [6], or triangle-based [4].

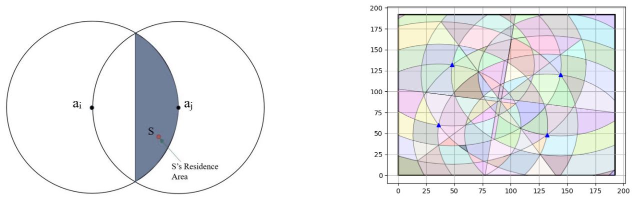
HALF SYMMETRICLENS (HSL). In this poster, we discuss the HSL [5], which is considered a range-free localization method that estimates proximity information among a node and a collection of k anchor nodes using received signal strength (RSSI) values: $A = \{a_1, a_2, ..., a_k\}$. This information is employed to compute the residential area of the node s concerning the group of nearby anchors. As depicted in Figure 1(a), HSL draws two circles with the center of the anchors for every anchor a_i and a_j of a node s. Our approach applies the cost function and constraints, which are discussed by Cheriet et al. [1]. Each of these circles has a radius that is equivalent to the distance between their respective centers. The geometric shape produced by the intersection of the two circles is termed a symmetric lens. The perpendicular bisector of the section linking the two anchors splits the symmetrical lens into two half-symmetric lenses, as shown in Figure 1(a). a_i and a_j, which can be represented as HSL (a_i, a_j) and HSL (a_j, a_i). The following cases are distinguished: 1. If s is more proximate to a_j relative to a_i, also a_i is nearer to s compared to a_j, consequently s is supposed to be in HSL (a_j, a_i). 2. If s is nearer to a_i than a_j, also a_j is nearer to s compared to a_i, then s is assumed to be in HSL (a_i, a_j). 3. If s is located at the beyond of both symmetric lenses, then it is out of both HSL (a_i, a_j) and HSL (a_j, a_i).

Problem Statement. In the plan for area-based localizations, the precision of a node's estimated position relies on the size of its residential neighborhood, which is adjustable through the deployment of the anchors. This study focuses on finding the optimal anchor locations for a specific number of anchors. This means that we are searching for a placement giving us the lowest average residence areas. Assume that in the service area S, K anchors $\{a_1, a_2, ..., a_k\}$ are deployed; due to this deployment and based on the HSL method, the area S is divided into m non-overlapping areas as it is indicated in Figure 1(b). The aggregation of these residential areas is equal to the size of the area, which is shown by S. The localizing nodes can be located in each of these areas; Cheriet et al. [1] proposed the following methodology for the problem: Let X denote a random variable that indicates the residence area of the node. Therefore $X \in \{s_1, s_2, ..., s_m\}$ based on the hypothesis the probability that node s is in the area of X is indicated as:

$$Pr[X = s_i] = \frac{s_i}{S} \tag{1}$$

The subsequent equation is applied to calculate the expected residence area regarding a node:

$$minimize : E[X] = \sum_{i=1}^{m} s_i Pr[X = s_i] = \frac{1}{S}\sum_{i=1}^{m} s_i^2 \tag{2}$$



(a) HSL Approach.

(b) Four anchor placement.

Figure 1

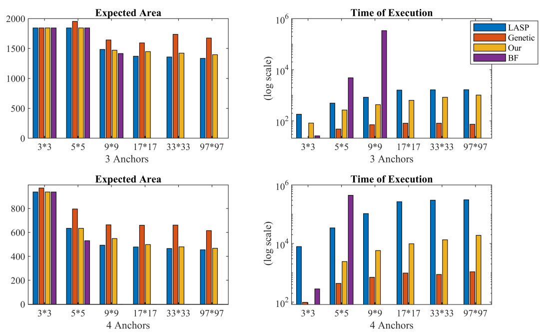


Figure 2: Results

2 Tabu Search Algorithm

Our work is based on the algorithmic framework of [1], but we use a Tabu search algorithm as optimization routine. The framework discretizes the area S that should be optimally covered by the anchors using a $p \times p$ grid of points, allowing for a good resolution and plenty of options for the anchor placement. We then applied a Tabu search algorithm (cf. [3]) to find the optimal anchor placement. Starting with a randomly generated solution or the solution imported from the previous step, which is represented by an array of anchor indices, the algorithm gradually converges by creating new solutions through a neighboring approach. The neighboring approach involves four actions: up, down, left, and right, which are applied to randomly chosen subsets of anchors. If a newly created solution is better than the current solution, it is considered the "Best_new.sol." To reduce computation time, only the positions of two anchors are changed in each iteration. If the algorithm finds a better solution, it puts the previous solution into the tabu list, which remains for the tabu length iterations. At the end of the algorithm, the best-ever found solution for that number of grid points is passed to the next level with a higher number of grid points.

3 Evaluation

For evaluation, we have incorporated our approach in the Python framework which is developed by Cheriet et al. [1]. To have a fair comparison we run their algorithms on our servers. Figure 2 indicates the results using 3 and 4 anchors for the grid sizes 3,5,9,17,33 and 97, sizes that were used in their paper. Our results indicate that we obtained the same solution quality but for 3 and 4 anchors we optimized the time of execution by by nearly 2 and 20 times, respectively.

4 Outlook

Due to the time-consuming nature of area calculation using Shapely, we plan to find an alternative method that allows us to get better solutions within a significantly reduced computational time.

Algorithm 1 Tabu Search Algorithm

Input:Tabu_Length, Anchor Number, Max_Iteration
Sol=random generated Solution or from the previous step
Best_new.sol
Best.sol=[]
Best_new.fitness, Best.fintness=inf
Action_list=Create_Action_list
procedure TABU(params)
    Best_new.fitness =inf;
    Best_new.sol =[];
    for $j = 0$ to $Length(Action\_list)$ **do**
        New.sol=Create_New_SOL(SOL_ACTION_LIST)
        New.fitness=Cost(New.sol)
        if $New.fitness < Best\_new.fitness$ **then**
            Best_new.fitness = New.fitness
            Best_new.sol = New.sol
        end if
        SOL=Best_new
        Update Tabu List()
        if $Best\_new.fitness < Best.fitness$ **then**
            Best.fitness = Best_New.fitness
            Best.sol = Best_New.sol
        end if
    end for
    Return Best.sol
end procedure

5 Acknowledgements

This research was funded by the Austrian Science Fund (FWF) DFH 5 within the DENISE project. For the purpose of open access, the authors have applied a CC BY public copyright license to any Author Accepted Manuscript version arising from this submission.

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