

Wi-Fi Received Signal Strength-based Indoor Localization System Using K-Nearest Neighbors fingerprint integrated D*algorithm

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Abstract—The indoor localization system is essential since the Global Positioning System cannot give an accurate position indoors, especially when several floor plans are considered. Wi-Fi received signal strength becomes an alternative indicator for indoor localization systems. The experiment proposed a localization system created by integrating and working between the K-Nearest Neighbors algorithm and the D*algorithm. The result illustrates the optimal path from the start point to the target point by avoiding the obstacle performing exceptionally well. The K-Nearest Neighbors algorithm provide the result for localization with Root Mean Square Errors of displacement at 1.190 meters, 2.491 meters, and 1.363 meters of X-Axis Y-Axis, respectively. The proposed indoor localization system can have various applications considering different environmental factors in different applications, such as the size of unmanned aerial vehicles when applying indoor unmanned aerial vehicles.

Index Terms—Indoor localization, Wi-Fi Received Signal Strength Indicator, K-Nearest Neighbor, D*Algorithm, Indoor positioning.

I. INTRODUCTION

Wi-Fi received signal strength (RSSI) can help to find a relationship between two positions to translate into distance values in indoor localization. Wi-Fi RSSI measures in decibel-milliwatts(dBm). The Wi-Fi RSSI values have typical negative values ranging between 0 dBm (excellent signal) and -110 dBm (low signal). Signal strength is taken to calculate the distance between nodes from the signal attenuation values. The Wi-Fi RSSI values are not complex to understand. If the RSSI value is high, it means the received signal is strong or high-quality, that is, the transceivers are close to each other, but if the Wi-Fi RSSI values are small, this indicates that the received signal is low or the system with the receiver and transmitter is far apart, depending on obstacles and the environment in which the signal has interfered. Examples of obstacles that can interfere with the Wi-Fi RSSI include walls, ceilings, objects, multiple routes, etc.

The K-Nearest Neighbour Algorithm (K-NN) is one of the simplest machine learning algorithms based on supervised

learning and non-parametric algorithms. Previous research has applied K-NN for indoor positioning since it does not have high complexity and its computing is not highly time-consuming [1] [2] [3]. The K-NN algorithm is a method used to classify. K value identifies the number of closest points that will be used to calculate the distance between those points and the current position, after which the mean of all K points is computed to obtain the predicted location [3].

The D*algorithm comes from the Dijkstra algorithm, which is used to determine the path of a robot's moves in eight directions. It is classified as a heuristic search algorithm because of its use of the heuristic technique. D*algorithms have been used widely, and D* algorithms will generate an optimal trajectory for the efficient planning of robot movements [4]. It is also used for route planning that results in unmanned aerial vehicle(UAV) flight routes by forming the "flying, judging, and planning" autonomous planning pattern [5].

In this paper, the implementation of the D*algorithm for a motion planning algorithm uses a starting point from K-NN in the localization process. Then, the target point and the position of the obstacle are assigned. The experiment is conducted on the map of a one-floor building of the Terminal 2 building at the International Academy of Aviation Industry in King Mongkut's Institute of Technology Ladkrabang. The paper is organized as follows: the next section is related work, which introduces the Wi-Fi RSSI, K-NN, and D*algorithm. Section III describes the proposed method. Section IV explains the results and discussion, and a conclusion is drawn in section V.

II. RELATED WORKS

A. WIFI Received signal strength indicator

RSSI stands for Received Signal Strength Indicator. The position of Wi-Fi RSSI in indoor localization systems is similar to that of Global Positioning System (GPS) in outdoor world mapping [6] since the GPS has insufficient inaccuracy when working indoors, especially because there are many floor plans. Therefore, Wi-Fi RSSI is widely used for indoor localization instead. The application can be used in several

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areas, such as office buildings, factories, and warehouses. Although Wi-Fi localization has an error of 1-2 meters because of the noise from other access points and attenuation from obstacles such as walls, it achieves better results than GPS for indoor localization. Wi-Fi RSSI shows high values when the position is close to the access point, whereas it shows low value when the position is far away from the access point. This concept has the advantage of computing the focused location.

B. K-Nearest Neighbors algorithm

K-NN is widely deployed in various applications. K-NN is a simple machine learning algorithm based on a supervised learning technique. The Euclidean distance is mostly the mathematics inside the processing as (1) and (2).

$$d(\vartheta, \varrho) = \sqrt{(\vartheta_1 - \varrho_1)^2 + (\vartheta_2 - \varrho_2)^2 + \dots + (\vartheta_n - \varrho_n)^2} \quad (1)$$

or

$$= \sqrt{\sum_{i=1}^n (\vartheta_i - \varrho_i)^2} \quad (2)$$

ϑ represents the first position, ϱ is the second position, and n is the number of data dimensions. Besides, the K value in K-NN should be set with a proper value to obtain a high level of prediction efficiency based on characteristic of data. K value is the number of points closest to the focused point that will be used to find the average value for predictions.

The dataset that will be used with K-NN must be separated into a training set and a testing set. In the experiment, 20% of the dataset is assigned to be the testing set and the remaining 80% is used for the training set.

C. The D*Algorithm

Traditional motion planning is designed for applications with one-time planning such as the A*algorithm. Therefore, it needs more programming to adjust to changes in the environment. The D*algorithm is developed for global use with a small modification or improvement for higher searching efficiency [7] [8] [9]. The D*algorithm is also known as the dynamic version of the A*algorithm without the heuristic function [4] [7] [10]. Both the A* algorithm and the D*algorithm are informed searches, and the A*algorithm has an evaluation function $f(n)$ as (3).

$$f(n) = g(n) + h(n) \quad (3)$$

where $g(n)$ and $h(n)$ are operating cost function and heuristic function, respectively. The D*algorithm process is to find the shortest path in graphs based on weight changes during the processing time. For every search node Z , the D*algorithm will calculate the operating cost function $g(n)$ of that path from the node Z to the target node, then compute the value of the critical function $k(Z)$ for re-planning processes. Consequently, the processes will store the old values of $g(n)$ before the changing of weights in the graph in the next processes.

III. METHOD

The proposed method presents a combination of processes between the K-NN and D*Algorithm. The K-NN is applied for localization of the current position, while the D*Algorithm optimizes the motion path to avoid the obstacle and reach the target point at the end.

Algorithm 1: The proposed method

Data: Wi-Fi RSSI at focused location, dataset, point of obstacle, target point

Result: Path planning

- Find current location by using Wi-Fi RSSI from the 4 access point implemented by K-NN and dataset.
- Set the location of obstacle.
- Set target point.
- Apply D*Algorithm for path planning.

The proposed method processes begin with collecting Wi-Fi signal strength by separating raw data into five columns. The first four columns are the Wi-Fi signal strength of the four access points, each located at a different point. The last column is the X and Y axis point, which can be transformed into a meter. The second process is K-NN modeling. It will apply the dataset for a training and testing set and consequently perform the K-NN process. The focused position will be identified by deploying the K-NN model from the previous process. Finally, when the obstacles and target points are assigned, the D*Algorithm can perform its task based on the mentioned parameters. The obstacles and target points can vary based on a set environment, such as a concentrated area floor plan.

IV. RESULT AND DISCUSSION

Raspberry Pi 3 is used to collect Wi-Fi signal strength, which is practical for various applications. Raw data includes both the signal and the noise from an undesirable access point that is always available while collecting data. The result of the experiment is more practical. Collecting data results in 8,360 records; as mentioned in the previous section, these records are divided into five columns, meaning that each of the 76 points has 110 records.

The experiment has been done in the Terminal 2 building in the International Academy of Aviation Industry at King Mongkut's Institute of Technology Ladkrabang. The building has only one floor and has the room alignment shown in Fig. 2. Also, Fig 2 demonstrates the position for four access points that focused on the experiment, which were located in 4 corners of the walkway. Each point in the walkway is assigned to an X-Y coordinate which has a distance of 1.2 meters.

Fig. 4 demonstrates the signal level which is obtained from four access points. It indicates that different signals from different access points show different patterns of data. According to Fig. 4, the signal from the access point number 1 has a peak signal at point 15, which is assigned to be the point (0,0). The signal from the second access point has a peak signal at point number 0, identified by (0,18) in the coordinate system. The third and the fourth access points have the highest signals at point number 55(30,18) and point number 40(30,0),

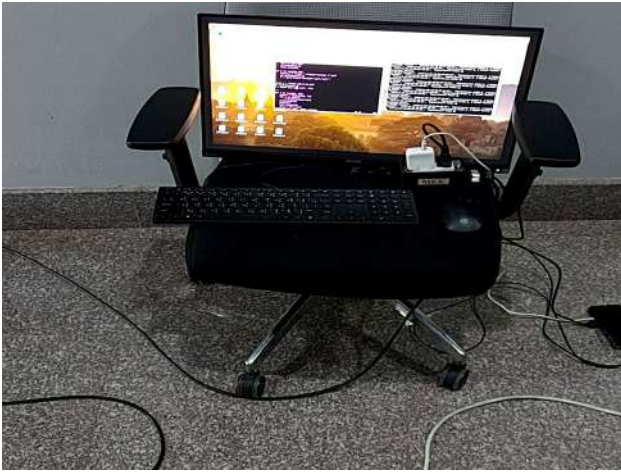


Fig. 1: Hardware for gathering value of signal strength.

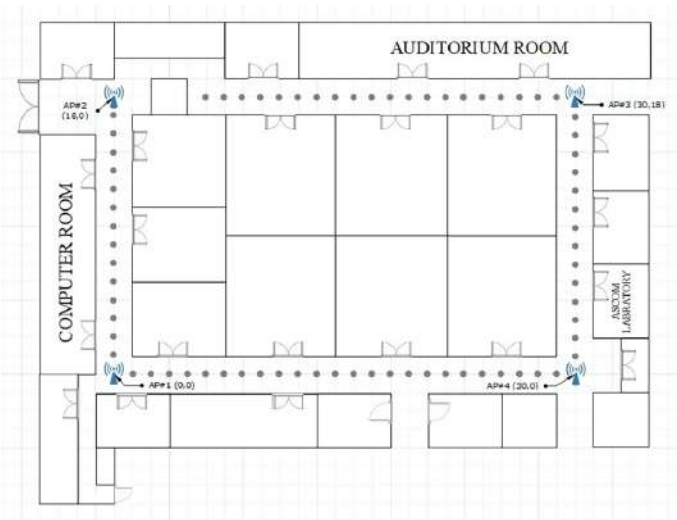


Fig. 2: Floor plan and location of the 4 access points.

respectively. The clear differences in the signal pattern support the model of the K-NN algorithm.

The first result is to evaluate the K-NN result as illustrated in TABLE I. The experiment set $K = 1$ and Root Mean Square Errors (RMSE) for displacement is 1.190 meters, while RMSE in the X-Axis and the Y-Axis are 2.491 and 1.363 meters, respectively. These error results are satisfactory for indoor positioning since typically the margin of error will be between 1-2 meters in displacement.

TABLE I: The result of K-NN algorithm

	RMSE (m.)
Displacement	1.190
X-Axis	2.491
Y-Axis	1.363

If the approximation of the floor plan equals 52 points in the X-Axis and 82 points in the Y-Axis, the map represents this with “.” symbol, and the area of an obstacle is represented by

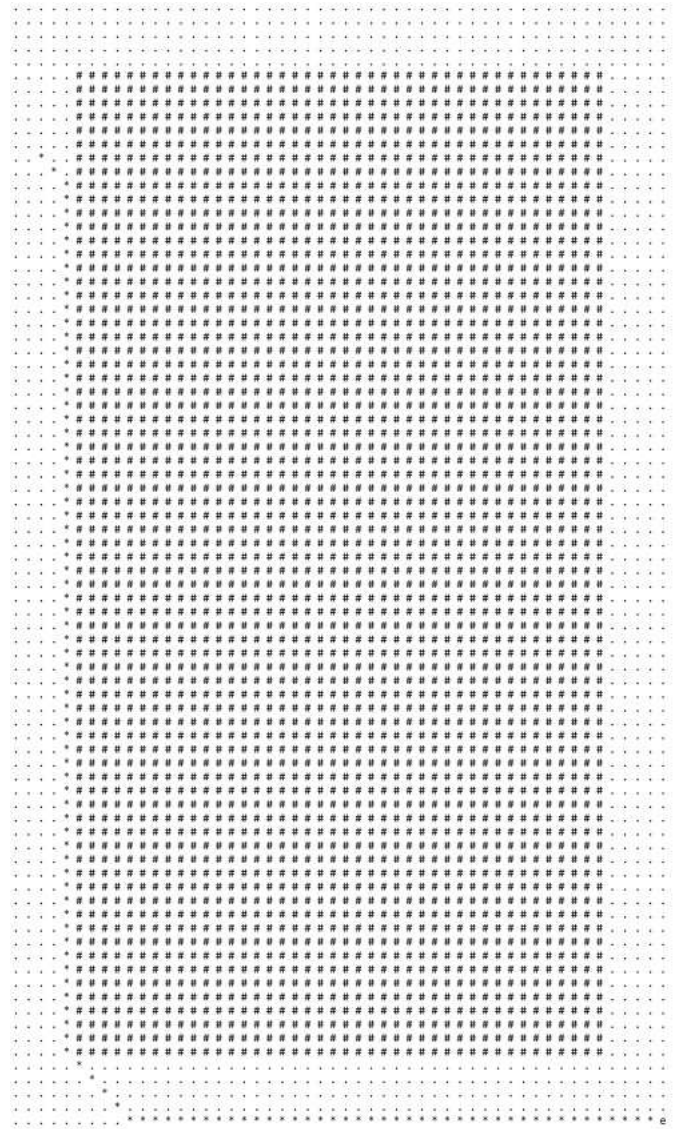


Fig. 3: The optimal path by D*Algorithm.

the “#” symbol. In the experiment, the points of (5,5), (77,5), (5, 47), and (77,47) are assigned as the positions of the corners of the obstacle. D*Algorithm has processes for finding the optimal path. The result of path planning is illustrated as the symbol “*” in Fig. 3

In the experiment, it is assumed that the initial location or start point can obtain Wi-Fi signal strength from different access points as follows:

- Access point No.1 = -45.0000
- Access point No.2 = -70.0000
- Access point No.3 = -82.1395
- Access point No.4 = -57.0000

These four values can obtain the current position, which is the start point. Then, the D*algorithm process for finding the motion path as demonstrating in Fig. 3 by “*” symbol. The optimal path will avoid the obstacle and reach the target point (52,82) in the final.

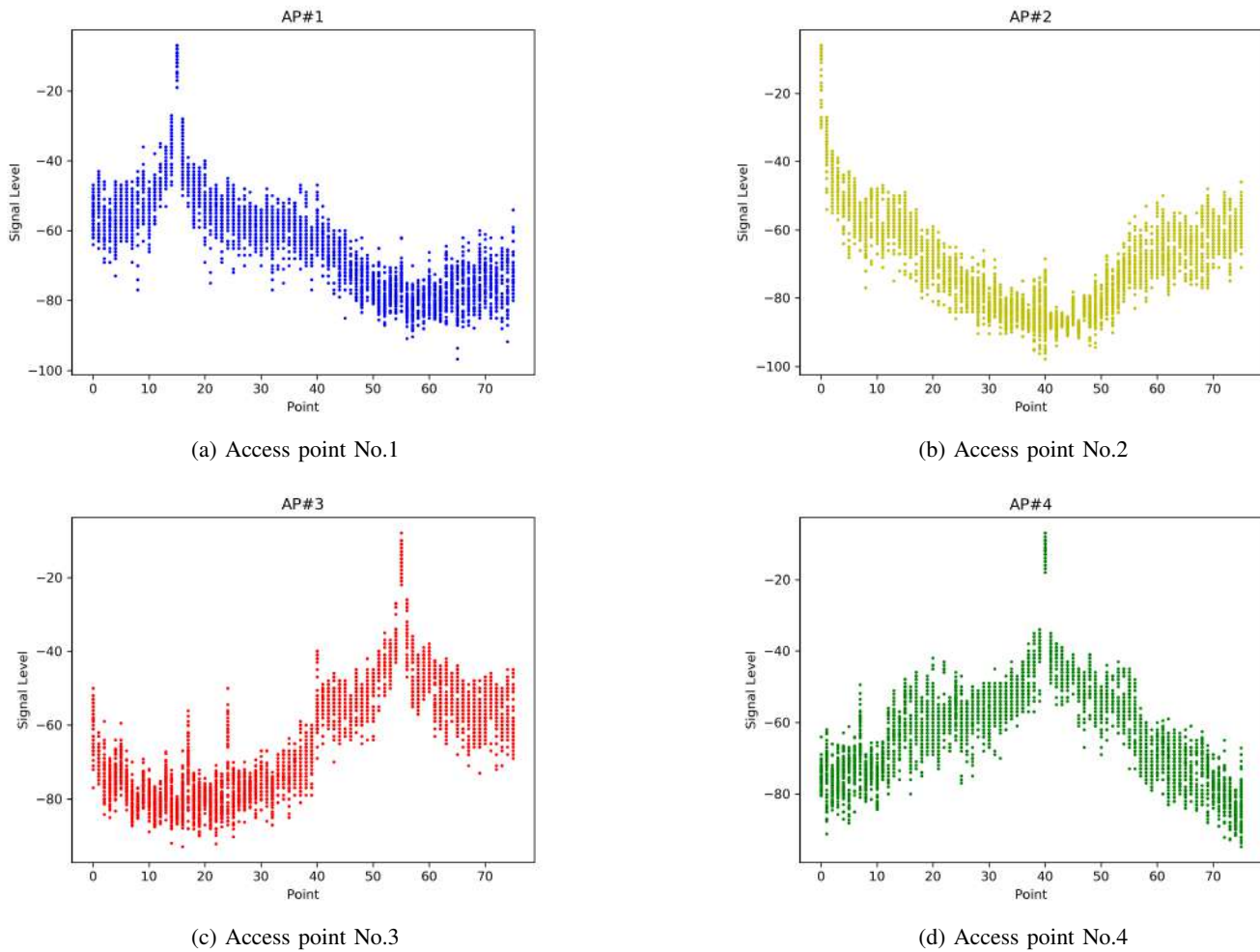


Fig. 4: Wi-Fi signal strength of each access point in different location

Many applications can apply this concept idea for path planning. However, attention must be paid to the map's scale as it applies to the K-NN and D*algorithm, which should correspond to each other to make the proposed method reach high efficiency. Moreover, other parameters should be considered based on the focused environment. For example, if the proposed method is implemented in an indoor UAV application, the proposed method is used for localization and motion planning of the UAV. Another critical parameter that should be considered is the UAV size, such as in the case of a large wing or propeller. The side of the map must be reserved for such a parameter.

V. CONCLUSION

This experiment presents the indoor localization system using the K-NN and D*algorithm applied to WiFi received signal strength. The experiment was conducted based on the Terminal 2 building map of the International Academy of Aviation Industry, King Mongkut's Institute of Technology Ladkrabang. It is a one-floor plan and separated into 76 points, each point has a distance of about 1.2 meters. The

data has been collected for 8,360 records and divided to a training set and testing set for K-NN modeling. The result of the model, when $K=1$, is very delightful for further process. D*algorithm is the consequent step that results from K-NN identifying the current location and setting it as the starting point. The map also approximates generated to present the obstacle at four corners of the building. D*algorithm generates the optimal path by avoiding the obstacle and reach the target point as set before. Although the proposed localization system provides a satisfying performance, other specific environments should be concentrated for instance, the size of the object or vehicles that would like to implement this localization system. Developers should pay attention to the sophisticated detail of map generation for the K-NN and D*algorithm, which should correspond to each other.

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