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Consideration of Shortening Search Time for Circulation Algorithm Operation in Disaster-Affected Areas

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***Abstract*—In today's highly information-oriented society, the number of people who own communication devices such as smartphones is increasing, and the flight technology of drones, a type of UAV (Unmanned Aerial Vehicle), is improving year by year. , UAVs are used to estimate the location of disaster victims who are carrying communication devices such as smartphones in places where people cannot see or enter based on Wi-Fi probe packets. In this paper, we aim to shorten the search time using a cyclic algorithm that has a high detection probability when assuming obstacles.**

***Index Terms*—UAV probepacket RSSI**

I. Introduction

A. Background and Objectives

In contemporary society, the proliferation of communication devices such as smartphones has increased (Reference: [1]). Additionally, advancements in the flight technology of Unmanned Aerial Vehicles (UAVs), commonly known as drones, have been notable. Against this backdrop, there is a growing emphasis on the ”72-hour barrier” in disaster situations, particularly since the Hanshin-Awaji earthquake (Reference: [2], Figure 1). Within this context, the importance of early detection and rescue is highlighted, with a specific focus on the early identification of disaster victims.

B. Positioning Method

As a positioning method, a technique utilizing the signal strength (RSSI: Received Signal Strength Indicator) of probe packets transmitted when mobile devices explore Wi-Fi access points is employed (Reference: [3]). This method capitalizes on characteristics such as the periodic transmission of signals by Wi-Fi devices and the attenuation curve exhibited by RSSI concerning the distance (Figure 2,Figure3).

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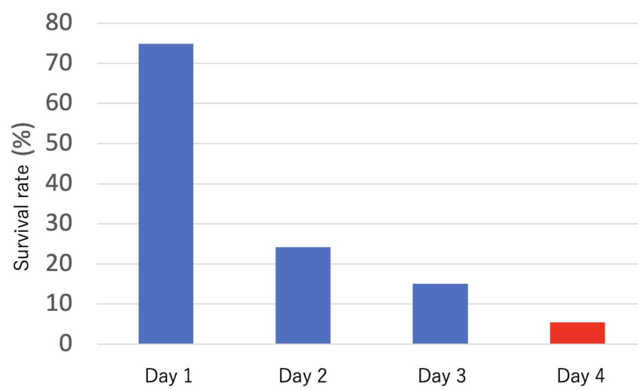

Fig. 1. Survival Rate Trends After the Hanshin-Awaji Earthquake

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2	2	6	6	6	2	可変長	可変長	4
frame control	duration	DA	SA	BSID	sequence control	SSID	support rate	Frame check sequence

Fig. 2. The Composition of Probe Packets

II. Proposed method

The existing method aims to achieve early detection by dividing a certain range into a grid and reducing the number of RSSI measurement points when exploring victim terminals, as outlined in the UAV algorithm [6]. In our proposed approach, we combine a direction-constrained algorithm, which estimates the approximate position of the terminal in advance to prevent incorrect route selection during the execution of the direction estimation algorithm, with an adaptation of the

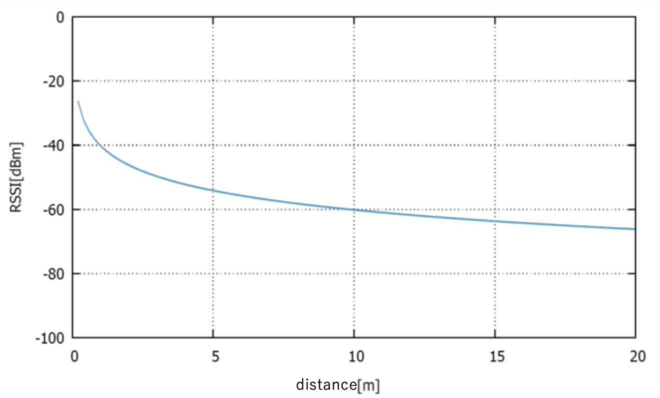

Fig. 3. The Received Signal Strength Indicator (RSSI) Attenuation Curve

algorithm's effective distance based on RSSI, taking into account features such as the attenuation curve observed in the RSSI of probe packets.

The procedure for the direction estimation algorithm is illustrated in Figure 4 and described below:

1) Set up a square (A) with the starting point as one of its vertices and the measurement interval as its side length.
2) Collect packets at the current location and record signal strength. If no packets are received for 60 seconds, proceed to step 3.
3)If measurements at all four vertices are completed, proceed to step 4. Otherwise, move to the next vertex of the square and go back to step 2.
4)Compare signal strengths at the four vertices and set a square symmetrically moved (B) as the point with the highest signal strength.
5)If the packet's signal strength is above -50dBm, consider a victim detected. Otherwise, repeat steps 2, 3, and 4.

The procedure for the direction-constrained algorithm is outlined in Figure 5 and described below:

1)Before the algorithm starts, perform RSSI measurements at four random points and calculate the average.
2)Set up a semicircle including the two points with the highest average.
3)During the execution of the direction estimation algorithm,allow movement only in the direction of the set semicircle.
4)If moving out of range, change the applicable distance and rerun the algorithm. If revisiting the same location for the second time, go back to step 1.

*The direction-constrained algorithm ends when the signal strength is below -70dBm (estimated to be within 30m for certain approach).

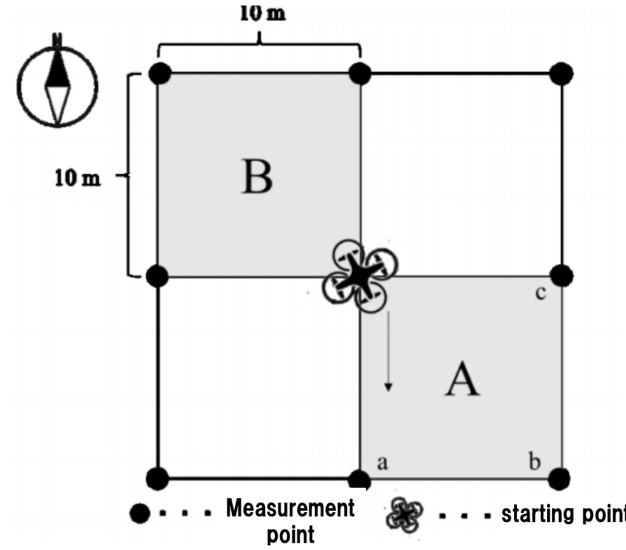

Fig. 4. Direction-estimation algorithm

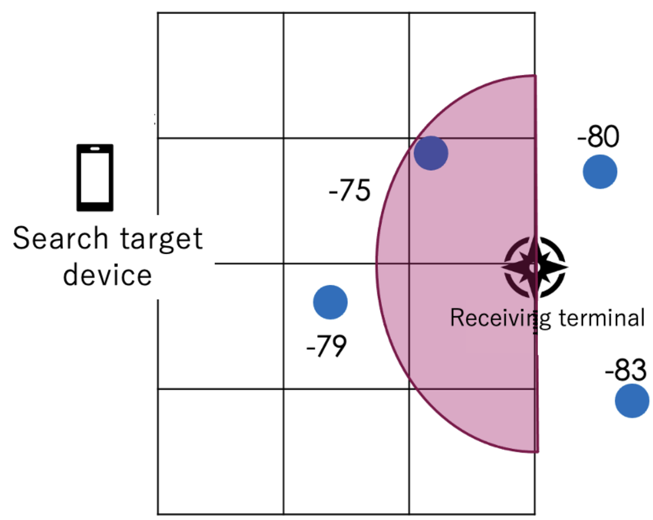

Fig. 5. Direction-limited algorithm

III. Related Methods

Moreover, regarding UAV×Wi-Fi probe packets, there are related methods such as the patrolling algorithm [7], where a UAV patrols a specified area to estimate congestion, and the Three-Point Localization Algorithm [8], designed for indoor positioning. The latter method utilizes pre-measured RSSI values at random three points to draw circles with estimated distances to respective devices as radii. The intersection of these circles is then used to estimate the presence of the device.

These methods are not necessarily designed for disaster-stricken areas or outdoor environments; some are intended for indoor environments or congestion estimation. In the subsequent chapters, we will investigate how these methods, including the proposed approach, differ in terms of discovery probability and exploration time when obstacles are considered in an outdoor environment.

IV. Preliminary experiment

A. Experiment summary

We will compare the patrolling algorithm, Three-Point Localization Algorithm, and the proposed approach, which are related methods, in an outdoor environment with assumed obstacles, similar to the preliminary experiments in Chapter 3. Each algorithm will be executed ten times in this environment. We aim to conduct a comparison along two crucial axes for operational use in disaster-stricken areas: device discovery probability and measurement time.

TABLE I
Patrolling Algorithm

Stop Time at Each Point	30 seconds
Stop Interval	2.5 meters both horizontally and vertically
Terminal Localization Method	Points with -60dBm or lower are adjacent and there are four or more
Judgment	Discovery when estimated position is within 5 meters error vertically or horizontally

TABLE II
Three-Point Localization Algorithm

Terminal Localization Method	Distance estimation to the device based on
Judgment	The method of estimating the device's position is he intersection of three circles. The actual terminal position is included in the estimated range.

B. Preliminary experiment

Below, detailed information on the use of related methods in the current experimental environment is presented in Tables I and II.

C. Results

The results for each algorithm are presented in Figure 6.

D. Consideration

Firstly, in terms of device discovery probability, the patrolling algorithm demonstrated the highest value. This is largely attributed to its ability to capture packets in areas with close distances to devices, where the RSSI variations are significant, by patrolling the entire designated area. However, due to the nature of the algorithm, patrolling all points in the search area resulted in redundant time-related costs. Nevertheless, for device discovery, capturing points with RSSI of -60dBm or higher in adjacent areas, i.e., areas with a direct distance of about 5m to the device, significantly contributed to device discovery. In these close-range areas, successful packet captures were achieved approximately 4-5 times with a stop time of about 30 seconds. Therefore, reducing stop time or avoiding packet capture during stops could address time-related issues.

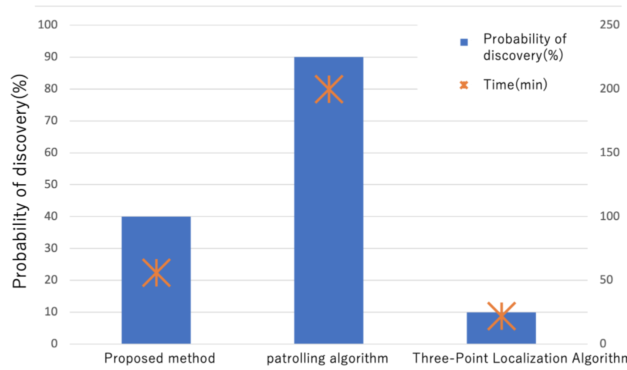

Fig. 6. Experimental Results

On the other hand, the Three-Point Localization Algorithm exhibited a lower discovery probability, and the discrepancy between the prior measured data used for device distance estimation and the actual data was considered a contributing factor to this lower probability. To improve accuracy, it is necessary to increase the number of prior measured data or the data measurement points. However, in terms of time, it was very short due to the small number of data measurement points (only 3 points). The patrolling algorithm showed a higher discovery probability than the conventional method, suggesting its feasibility for use in disaster-stricken areas. However, due to the nature of the algorithm, it required much longer time for each search compared to the conventional method, highlighting the challenge of reducing time-related costs. One potential solution is to consider the arrival time of the captured packets, which could be addressed by capturing packets while moving.

V. Main Experiment

A. Experiment summary

We conduct experiments with the aim of reducing the time cost of the cyclic algorithm, which is one of the related methods and has high accuracy and high time cost. Details in the table below.

TABLE III
Three-Point Localization Algorithm

Environment Setup	Prepare an environment similar to the preliminary experiment
Velocity Settings	Set velocities such that it takes 1s, 2s, and 3s to advance 1m, respectively
Execution	Execute the experiment 10 times at each velocity. Perform position measurement while moving without stopping, utilizing arrival times
Data Collection	RSSI, arrival times

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B. Result

We present the discovery probability and the number of packets captured per unit time at each velocity in both figures7 and tablesIV.

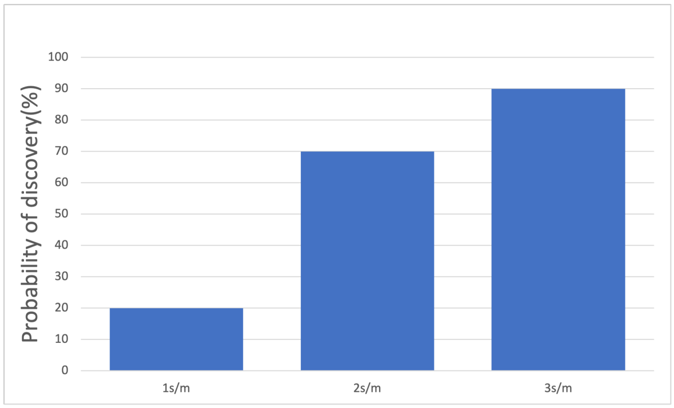

Fig. 7. Probability of discovery

TABLE IV
NUMBER OF PACKETS ACQUIRED PER UNIT TIME

1s/m	2s/m	3s/m
0.1	0.22	0.48

C. Consideration

From the graph results, it can be inferred that at 1s/m movement, the number of captured packets is limited, indicating inadequacy. This limitation arises due to the inability to capture packets at close distances to the targeted devices, a crucial aspect in position estimation.

Conversely, at 2s/m and 3s/m, the ability to capture packets at close distances to the intended devices is higher, rendering them suitable for position estimation. However, reliance on arrival time introduces a challenge: the discrepancy between packet transmission time and arrival time results in a broader gap between the estimated position and the actual location, compared to stationary measurements.

VI. CONCLUSION

this study aimed to reduce search time in disaster scenarios within the context of patrolling algorithms, known for their time-cost inefficiencies. Leveraging arrival times in packet information was intended to expedite search efforts. However, the discrepancy between packet creation and arrival time poses a challenge. It is anticipated that addressing this issue, perhaps by considering this time difference in the utilization of arrival time, could resolve the problem satisfactorily. Further efforts will focus on resolving this issue in subsequent studies.

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