Simply Tag and Find: Finding Indoor Items by Using Detection History of RFID Tags

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Abstract
We propose a novel method for locating tagged items that uses a RFID reader, a smartphone, and unregistered RFID tags attached to a variety of items, furniture and places. As a user moves through a room to locate a target item, our system shows relative distances to the target item and images of items on the way to the target. At the same time, the system scans RFID tags nearby and captures images for scanned RFID-tagged objects. This information is accumulated in a database and is accessible for future item location activities. Since all information was gathered during users' searching activities, the proposed system does not require users' effort for managing and registering tags. We asked 10 users to compare our method with the conventional method, which shows RSSI of the target item, of searching for the target item. The results suggest that our method is effective for location target RFID-tagged items.

Author Keywords
RFID; search; relative positioning; mobile application

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces.

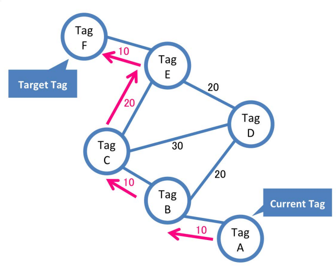

Figure 1: Undirected graph for estimating relative distances between tags. The length of the edge represents as the relative distance. Pink arrows indicate the shortest path from the current item to the target item calculated using Dijkstra's algorithm.

Introduction

Many people consume much time to find out missing items in a daily life. There are various systems for finding indoor items using RFID tags. If RFID tags are attached to various items, people could search items by using tags Received Signal Strength Indicator (RSSI). Nakata et al. used active RFIDs and ultrasonic position detectors to find items [2]. Nickels et al. implemented a location system combined active RFIDs with ZigBee [3]. Iteminder[1] is a location system that uses passive RFID tags for items and specific places. A moving robot locates each item by using the attached tag and location tags. These method require the registration of many tags' information (i.e., position, name, etc.). Our method reduce users' effort for registering tags by gathering information during users' searching activities.

Application

This system consists of passive RFID tags [1] , a RFID reader [2] , a smartphone, and a server. The system runs JAVA on Android OS 5.0, PHP and MySQL on Ubuntu Server. Figure 2 shows the system diagram. The preparation for this system simply requires users to tag of items, furniture and places. There is no requirement for registering the positions and names of tagged items because relative distances and the pictures of tagged items are continuously updated as the user traverses the room in search of items. The user can identify tagged items by image. The user can find the position of the tagged target item by navigating through the tagged items that are in increasingly closer proximity to the target item. The relative distances between tagged items are estimated by the undirected graph as shown in Figure 1. This graph is continuously updated by using the information gathered during previous and current user's searching

[1]Short Dipole, 900MHz passive tags
[2]DOTR-920J, Max 1W, 916.8MHz-920.8MHz

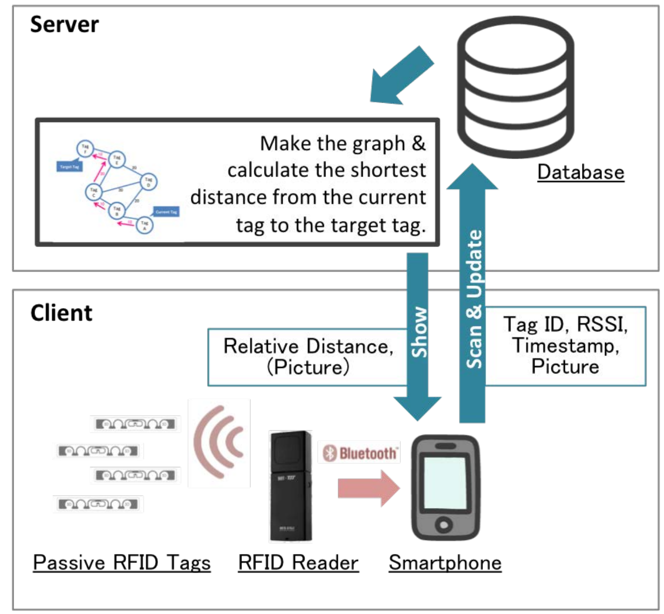

Figure 2: System diagram from tag detection to relative distance between tagged items.

activity. The length of an edge represents a relative distance calculated by our algorithm. The following shows the outline of our algorithm. The length gets shorter when two tags are detected simultaneously because two tags are estimated to be closer. [3] When two tags are detected separately, they are estimated to be in different areas and the length gets longer. According to the following detailed method of our algorithm, the edge lengths of the graph are adjusted using the scanning data for each tag. The edge length between a pair of tagged items, Tag A and Tag B, is

[3]Detecting tags simultaneously means tags are within 100 centimeters because our used RFID reader can detect tags within 100 centimeters.

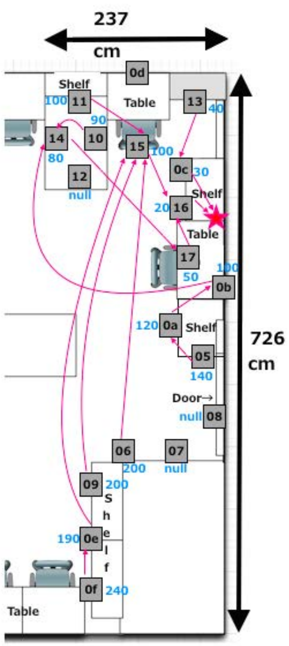

Figure 3: Map of the experimental room. Gray squares mean names of tags. A red star means the target tag. Blue numbers mean relative distances of each tags. Pink arrows indicate the shortest route from each tags to the target tag.

set to 10 when the two are scanned simultaneously. Therefore, the minimum distance between the items is 10 units. Each time a pair of tagged items is scanned separately, 10 units is added to the edge length. The shortest path to the target item indicated by pink arrows in Figure 1 is calculated using Dijkstra's algorithm.

Figure 4 shows the flow diagram of this application. First, the user selects the target picture in the smartphone screen. Then, the user repeats to scan the nearby tags to see the relative distance shown on the application until the user locates the target item. In the application screen, the relative distance is shown as a bar. The length of bars means the relative distance from the scanned tag to the target tag. The bar gets longer or shorter when the relative distance is far or near. The bar color changes as the relative distance gets shorter or longer compared to the existing bar length. If the relative distance gets longer, the user is headed in the wrong direction. When the application has pictures of the next tagged item [4] on the way to the target item, the application shows them. The user can find the target item by navigating through relative distances and images of tagged items that are in increasingly closer proximity to the target.

Experiment

We carried out an experiment for comparing our proposed method with a conventional search method using RFID. The experiment consisted of subjects using two different methods to search for a target item in a room. One method is our proposed system that shows relative distances to the target item and images of tags on the way to the target. The other method shows RSSI of the target tag. In these method, when the user pressed the trigger button on the

[4] The next tag means the tag next to current tag on the shortest route to the target tag estimated by Dijkstra's algorithm.

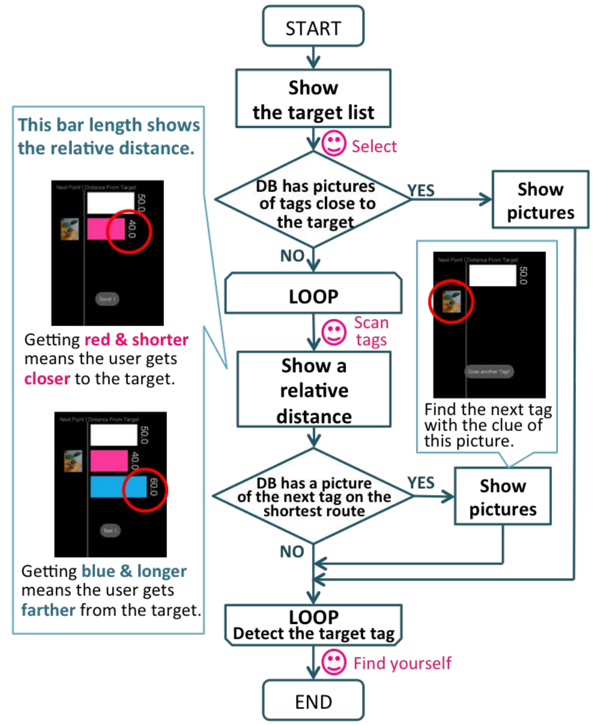

Figure 4: Flow diagram of the application from the app beginning to the end of the users' searching activity.

RFID reader, a scan was conducted and the display is updated. We compared the efficiency and ease of use of both methods by recording the elapsed time and the number of scans used to find the target item. In preparation for this experiment, 20 items, furniture and places were tagged with passive RFID tags in a part of our laboratory, as shown in Figure 3. Tagged items were positioned between 60 and 160 centimeters in height and the maximum distance between each item was approximately 50 centimeters. Con-

Table 1: Results of the experiment. 1. is the conventional method. 2. is our proposed method.

user No.	1. time (ms)	2. time (ms)	1. scan cnt	2. scan cnt
1	236	71	375	4
2	165	61	71	16
3	199	72	75	19
4	95	102	48	34
5	139	33	102	7
6	96	133	47	43
7	330	102	150	9
8	45	42	10	4
9	78	32	25	3
10	82	58	18	7

sidering that the coverage of the RFID reader is 100 centimeter, we expect the tag density be high enough to guide users to the target. Before the experiment, one of the authors scanned all the target area using approximately 30 centimeters intervals, to emulate previous searching activities. As a result of the author scanning, the proposed system calculated the relative distances between each tagged item and the shortest route to the target, as shown in Figure 3.

We asked ten students (1 male and 9 female, age 21-27) to participate in our experiment. Table 1 shows subject scores. For all subjects, the target item was located using less number of scans with our proposed method than with the conventional method. Target items were located faster by our method than with the conventional method in 80% of the cases. These results suggest that our proposed method may be superior to the conventional method in terms of efficiency. Feedback was gathered from each of the subjects. Based on this feedback, improvements to the smartphone display should be considered.

Conclusion and Future Work

We implemented a novel indoor item location system using relative distances of RFID tags. Our main purpose is reducing the costs of managing RFID tags by using information accumulated from previous searches of unregistered tags. In this experiment, our proposed method was effective and efficient in locating target items at a low cost. In future, we seek to improve the efficiency of our algorithm by considering the “mobility“ of each tag because some items are moved frequently in a daily life. For instance, the “mobility“ of a TV remote control may be high relative to the “mobility“ of the surrounding furniture. We plan to create a virtual room in order to simulate the scanning activity of virtual tags and evaluate the usability of our method including "mobility". Then we will conduct additional experiments explore whether our proposed method is useful under a variety of circumstances, including when items are moved between scans as may occur in routine daily activities. We will also explore opportunities for improving the accuracy of tag detection not only by human users but also by using automatic orbiting robots such as RFID reader equipped cleaner robots.

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