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A fuzzy collaboration system for ubiquitous loading/unloading space recommendation in the logistics industry

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ABSTRACT

A fuzzy collaboration system was designed for ubiquitous loading/unloading space recommendation in the logistics industry. The designed system allows drivers to share information regarding the availability of loading/unloading spaces without providing the exact number of available loading/unloading spaces, thus promoting drivers to use the system. To derive the exact number of loading/unloading spaces from the inexact information, a quadratic programming problem was formulated and solved. In addition, driver location and speed were modeled using fuzzy numbers to account for the uncertainty of their locations. Subsequently, fuzzy cross-referencing was used so that loading/unloading space information can be referenced from more than one location. The proposed methodology was applied to a small region in Seatwen District, Taichung City, Taiwan. The designed system reduced the average time required for a driver to locate a nearby loading/unloading space by 72%.

1. Introduction

With advances in wireless networks, smartphone development has peaked. According to OurMobilePlanet [1], smartphone penetration rate has exceeded 51%, and smartphone applications (apps) are being developed rapidly. Apps are useful in not only in daily life but also at work. Gartner, an international research and consulting company, noted that mobile apps were downloaded 100 billion times in 2013 [2]. They predicted that by 2017, free app downloads will account for 94.5% of all app downloads. Compared with the data from 2012, this is a substantially increase of 89.6%, as shown in Appendix A. According to the smartphone usage behavior report by Insightxplorer [3], considerable gender differences exist in the use of apps. Nevertheless, location-based services (LBSes or mobile guides), such as Google Maps, rank among the top five regardless of gender, as listed in Appendix A.

Future app development will focus on fast, flexible, and interactive applications. In addition, precision and timeliness of the information and services provided will be increasingly emphasized [4]. Further, social networking and LBSs are the two most utilized app types (Appendix A). Combining these two types of apps results in a new service: location-based social network (LBSN) [5]. Coppens et al. [5] conducted a qualitative study to analyze users' location-sharing behavior by using various privacy scripts in two LBSNs. The results showed that the privacy script influences users' perceived control over their context information. To assess the performance of an LBSN for tourists, Kremer and Schlieder [6] adopted three data sources: interviews, global positioning system (GPS) tracks, and georeferenced photo sequences. According to Stroeken et al. [7], the focus of an LBSN should shift from person-based to goal-oriented communication. In addition, collaboration among distributed participants is also a critical research trend in advanced manufacturing [8–9].

The applications of ubiquitous computing technologies in manufacturing are typically based on service-oriented architectures [10]. Such applications are distributed among the stages of a product life cycle, from research and development to design [11], manufacturing [12–13], logistics [14], and customer service [15]. Specifically, in logistics, radio frequency identification (RFID) tags have been used to identify goods to avoid misplacement, and weight sensors have been installed to avoid vehicle overload [16].

In this study, a fuzzy collaboration system was constructed for ubiquitous loading/unloading space recommendation in the logistics industry. Without loading-unloading spaces, delivery vehicles must park on the roadway lanes and this generates negative impacts in terms of road capacity and safety [17]. This issue is therefore critical to the logistics industry. In the literature, Liu et al. [18] combined rough set and fuzzy logic, and proposed a heuristic to determine the locations of distribution centers. Zhang et al. [19] built a node-weighted bottleneck Steiner tree based multi-objective location optimization model for establishing an emergency logistics system. In addition to these standing facilities, some loading/unloading spaces are also required to support the smooth operations of a logistics company.

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The fuzzy collaboration system is a dynamic LBSN, in which drivers form a dynamic social network and guide each other by sharing their context information, as described herein:

(1) Drivers: Users of the fuzzy collaboration system are drivers moving at various speeds—a feature that distinguishes the fuzzy collaboration system from a conventional LBSN.
(2) Dynamic social network: The members of the fuzzy collaboration system keep changing as drivers enter and leave the collaboration region.
(3) Context: According to Stroeken et al. [7], the goal of communication is critical to the effectiveness of an LBSN. In the proposed methodology, the goal of communication is to share information regarding the availability of nearby loading/unloading spaces. Therefore, the location and speed of a driver, the availability of loading/unloading spaces around the driver, and other relevant information are essential variables of the proposed methodology.

The designed system addresses a critical problem because in crowded cities, locating available parking or loading/unloading spaces is extremely challenging. According to the Institute of Transportation [20], approximately 30% of the detoured traffic on roads is searching for parking or loading/unloading spaces. Therefore, effectively providing parking or loading/unloading space information to drivers is a vital task. Existing parking space recommendation systems assist drivers through two approaches. In the first approach, drivers must install and use the client-side app to input their queries on the availability of nearby parking spaces. The query input by the driver and their location and speed are transferred to the system server for processing. Finally, the recommendation result is communicated to the driver. Well-known examples in this category include ParkMe (https://www.parkme.com/), Parking Panda (https://www.parkingpanda.com/parking-app), and EasyPark (http://www.easypark.ca/easypark-lots/mobile-parking-app.aspx). In the second approach, a driver must visit the website of a service provider to perform the aforementioned tasks. Well-known examples in this category include ParkMe, Taipei City Parking Guidance Information System (http://tpis.pma.gov.tw/ParkInfo/realinfo), and others. Recent relevant studies have focused on advanced reasoning methods. For example, Chen et al. [21] developed a system for recommending the best parking station by using fuzzy inference rules to compare the alternatives. Xia and Irawan [22] extended the method proposed by Chen et al. to consider multiple criteria.

A client-side app often restricts the options that can be provided to a driver because of the limited screen size. By contrast, the advantages of using a client-side app include the high speed of querying and focusing on the results. Through the website of a service provider, a driver can input their query by using several means and obtain detailed loading/unloading space information. However, the querying process may be lengthy, which may discourage a driver from using this system. In both approaches, the usefulness of the loading/unloading space information to a driver is dependent on the system server's ability to continuously update its database. In addition, most existing systems only provide information on available loading/unloading spaces in major loading areas and not on the sides of the roads. Furthermore, the interaction between a system server and the drivers is unidirectional, that is, the system server does not encourage feedback from the drivers; an exception in cases where the correct loading/unloading space information can be emailed to the system administrator (Fig. 1); however, this information must be verified and therefore will not be updated within an acceptable time. Owing to various speeds and angles of view, the number of loading/unloading spaces at a location reported by various drivers frequently differs; therefore, they must collaborate.

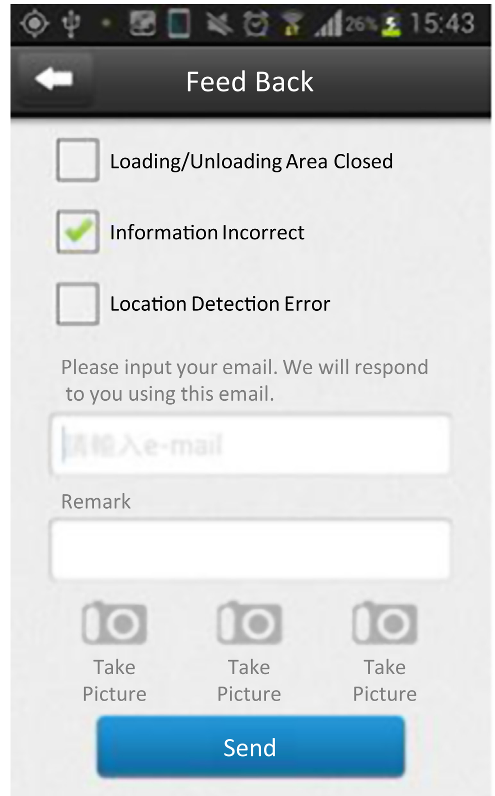

Fig. 1. Correcting loading/unloading space information through emails.

To solve the existing systems' problems, the proposed methodology applied fuzzy logic and ubiquitous computing to establish a fuzzy collaboration system for ubiquitous loading/unloading space recommendation, in which

(1) A driver's location is detected using the GPS system available in the smartphone. The result is subject to imprecision modeled using fuzzy logic. Kuo and Chen [23], Lin and Chen [4], and Chen [24] have conducted similar studies.
(2) A client-side app is used by the driver to locate nearby loading/unloading spaces.
(3) The driver provides information regarding the availability of loading/unloading spaces to the system server using the same app, which relieves the system server of collecting such information. Hence, the loading/unloading space data is precise and updated.
(4) A driver need not provide exact information; this reduces their burden and encourages them to use the system.
(5) Driver-provided loading/unloading space information is aggregated using the system server. Thus, drivers can collaborate indirectly.

The remainder of this paper is organized as follows. Section 2 describes the architecture and process flow of the fuzzy collaboration system for ubiquitous loading/unloading space recommendation. The modeling of a driver's location and speed and the availability of loading/unloading spaces by using fuzzy sets is described in Section 3. The feedback mechanism on the client side and aggregation mechanism on the server side are proposed. The proposed methodology was applied to a small region in Seatwen District, Taichung City, Taiwan to assess its effectiveness, which is detailed in Section 4. Finally, Section 5 concludes this paper.

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