Poster - FooDNet: Optimized On Demand Take-out Food Delivery using Spatial Crowdsourcing

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ABSTRACT

This paper builds a Food Delivery Network (FooDNet) that investigates the usage of urban taxis to support on demand take-out food delivery by leveraging spatial crowdsourcing. Unlike existing service sharing systems (e.g., ridesharing), the delivery of food in FooDNet is more time-sensitive and the optimization problem is more complex regarding high-efficiency, huge-number of delivery needs. In particular, we study the food delivery problem in association with the Opportunistic Online Takeout Ordering & Delivery service (O-OTOD). Specifically, the food is delivered incidentally by taxis when carrying passengers in the O-OTOD problem, and the optimization goal is to minimize the number of selected taxis to maintain a relative high incentive to the participated drivers. The two-stage method is proposed to solve the problem, consisting of the construction algorithm and the Large Neighborhood Search (LNS) algorithm. Preliminary experiments based on real-world taxi trajectory datasets verify that our proposed algorithms are effective and efficient.

KEYWORDS

Spatial crowdsouring; food delivery; optimization

1 INTRODUCTION

In recent years, with the prevalence of the mobile Internet, Online Takeout Ordering & Delivery (OTOD) using smart phones has become an emerging service (e.g., KFC delivery). In the OTOD service, the user could get the take-out food delivered by the restaurant staff after ordering online. In addition, some online delivery platforms are developed as the new model of the OTOD service (e.g., ele.me [1]). Different from the traditional delivery method that take-out food is delivered independently by staffs of different restaurants, multiple merchants registered in these platforms could share the resources of professional delivery staffs to reduce the delivery cost. In general, the OTOD service is convenient and time-saving especially for people who are taking rest at home or busy working.

Though having rising development in the last few years, existing OTOD services still have some limitations. First, food delivery is usually completed by using bicycles or electric motorcars rather than cars in view of the delivery cost, which reduces the delivery efficiency and results in the limited delivery range because of the slow speed. Second, most of food orders appear in the same time period (e.g., lunch and dinner times), which could lead to a lot of delivery requests in a short time duration. Therefore, it becomes difficult to deliver the food on time during the rush hour because of a fixed number of delivery staffs. In addition, the resources of professional delivery staffs may be wasted when there are few delivery requests during the most part of a day. So a new method is under investigated to tackle these challenges.

Spatial Crowdsourcing (SC) is an emerging paradigm that extends traditional crowdsourcing to the physical world, by assigning location-based tasks to moving workers to complete [3, 4]. In this paper, we view the OTOD service as a special type of SC task, which refers to object delivery that delivers objects from one place (i.e., restaurants) to another place (i.e., food orders). Recently, there have been several works that try to combine SC and object delivery. For example, Chen *et al*. [1] proposed a package delivery system, namely CROWDDELIVER, where packages share the resources of vehicles with passengers. Inspired by previous studies, we devote to building a food delivery network that uses an abundance of taxis in the road network to deliver food packages. For taxi drivers, extra income from the food delivery service can be obtained to promote the long-term engagement. For passengers, sharing the resources of taxis with food could reduce the taxi fare, and increase the riding comfort without sharing the limited space of the taxi with other strangers in ridesharing. For restaurants, delivering food using existing resources of urban taxis can decrease the cost on recruiting extra delivery staffs, and enable the long-distance food delivery.

To the best of our knowledge, this is the first work that studies the efficient delivery network by sharing rides of passengers and food packages using taxis. Most of current works mainly focus on the package delivery [2], which is significantly different from food delivery as investigated in this work. First, food delivery has more strict ‘pick-up’ (the restaurant) and ‘arrival’ (the food order) time constraints to ensure the quality of food and meet users’ dining demands. Second, the food package is usually smaller in size compared with other types of packages, and a taxi could serve more food orders to increase the delivery efficiency and lower the cost. Third, a taxi may be required to visit multiple locations to deliver the food because of various food orders with different restaurants and users, which could result in a more complicated optimization problem on delivery task assignment. Therefore, the solution of food delivery using SC is still to be further explored.

[1] http://www.ele.me

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To address the above challenges, we propose FooDNet, which is a novel food delivery network that achieves the OTOD service based on spatial crowdsourcing. In particular, we solve the Opportunistic OTOD (O-OTOD) problem by leveraging pervasive taxis running in cities. In O-OTOD, taxis with carrying passengers deliver the food with low cost using spatial crowdsourcing. Specifically, we define the places of the restaurant and the requester in the food order as starting and destination areas. If the order happens in the frequent-interaction areas (i.e., there are more taxis running between the starting and destination areas), the taxi can deliver the food package opportunistically. In general, we have made the following contributions.

1. We present a novel system to deliver the take-out food by leveraging existing resources of taxis. To the best of our knowledge, it is the first work that applies spatial crowdsourcing in the OTOD field.
2. We elaborate the O-OTOD problem that the food is delivered incidentally by taxis when carrying passengers, and the optimization goal is to minimize the number of selected taxis.
3. We propose the two-stage method to solve the O-OTOD problem, which consists of the construction algorithm and the Large Neighborhood Search (LNS) algorithm. Specifically, the construction algorithm constructs an initial solution, and LNS optimizes the original solution by removing and inserting food requests.
4. We have conducted initial experiments using real-world taxi trajectory datasets to test the performance of FooDNet. The results indicate that our proposed algorithms are effective and efficient compared to baseline methods.

2 SYSTEM DESIGN

2.1 System Overview

The proposed FooDNet framework is shown in Fig. 1.

Pre-ordering food: The system has three stakeholders, namely restaurants, taxi drivers, and users. Specifically, it provides some information of restaurants for users to order the food, including the location, the business hour, and the food category. Meanwhile, information of taxis is also collected, i.e., the current location, the historical trajectory, and the passenger's request. When users start to order the food, they should provide the request information, including the location, the mealtime, and the kind of food.

Accepting food-delivery request: When the user starts an order, the system then determines whether to accept it. Based on the information of restaurants and taxis, as well as the user's food request, the system will accept the food-delivery request if it satisfies constraints (e.g., the time of ordering food can be 30 minutes earlier than the mealtime).

Selecting taxi for food delivery: For the accepted requests, the system will select proper taxis to deliver the food. The selection method is mainly divided into two steps. First, we apply the heuristic algorithm to construct the initial feasible solution. Second, LNS optimizes the original solution by removing and inserting food requests. Finally, the optimized solution is obtained, i.e., the planned route of each selected taxi to deliver the food.

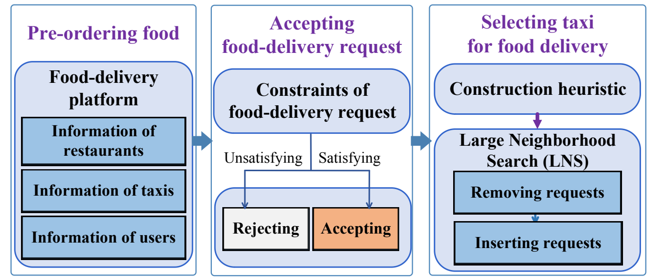


Figure 1: An overview of FooDNet.

2.2 Problem Statement

Food is delivered in the O-OTOD problem incidentally when taxis carry passengers. For the taxi, in view of the priority of the passenger, the taxi should pick up all food packages before picking up the passenger, and deliver the food after the passenger takes off. We assume that the passenger is willing to wait for a relatively short time period (e.g., 10 minutes) cost on picking up food packages as we can give her/him discounts for shared-riding.

Assume that there are a number of available taxis with passenger demands in the system, and a sequence of food orders with different time requirements that need to be delivered on time. Note that the food-delivery request is associated with two spatial points where the taxi has to visit: its *origin*, where the food is picked up at the restaurant, and its *destination*, where the taxi delivers the food package to the user. The *optimization goal* of the problem is to minimize the number of selected taxis in order to increase the income of each taxi driver and attract more drivers to participate over the long-term running. In addition, the optimal route of each selected taxi should be planned to deliver the passenger and food. Note that the planned route of the taxi have to satisfy the time constraints of passengers and food-delivery requests, such as any food request must be delivered within a given time period, and the extra time of the taxi to pick up food should be less than the maximum waiting time of the passenger.

2.3 The Algorithm Design

Obviously, the O-OTOD problem is known to be an NP-hard problem [5]. Moreover, many constraints of food requests and passengers make the problem more complicated. In general, there are two challenging issues to be addressed. One is to assign food-delivery requests to appropriate taxis among plenty of taxis with different passenger demands. The other is to plan the best route of the taxi to deliver the food under different constraints. Therefore, we propose the two-stage method to solve the O-OTOD problem, consisting of the construction algorithm and the LNS algorithm.

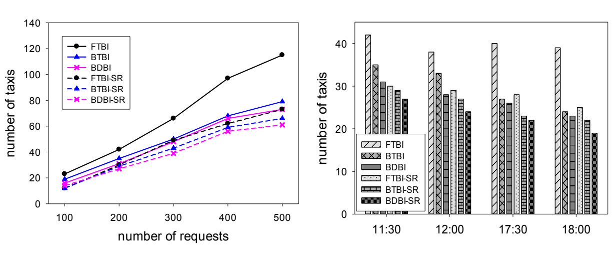
2.3.1 The construction algorithm. The construction algorithm obtains the initial feasible solution by selecting proper taxis for each food-delivery request. In general, we propose three greedy methods to get the feasible solution of the problem: First Taxi (*FT*), Best Taxi (*BT*) and Best Delivery (*BD*). *FT* inserts the food-delivery request in the route of first appropriate taxi while satisfying all constraints of food packages and the passenger. *BT* selects the best taxi among all available taxis that minimizes the increase in the cost of the solution after the insertion process. *BD* chooses the best food-delivery request whose insertion causes the least increase in the overall cost of solution among all the un-delivered food requests.

2.3.2 The LNS algorithm. LNS optimizes the initial solution obtained by the construction algorithm, and it can move from one promising area of the solution space to another to jump from local optimal solution and guide the search in global solutions. In general, LNS includes two parts: one is removing a number of food requests delivered by the taxi from the current solution, the other is reinserting these requests in the current routes of taxis again. Specifically, we propose two methods to remove and insert food-delivery requests: Shaw Removal (*SR*) and Best Insertion (*BI*). *SR* removes some similar food-delivery requests, because there is a little influence among different requests, and we may reinsert the removed requests at original positions or some bad positions which could lead to small change or no change of the initial solution. In addition, *BI* selects the best position which has the minimum increasing cost from all available positions of multiple available taxis' routes to insert the food-delivery request.

3 PRELIMINARY EVALUATION

We evaluate our system based on three kinds of real-world datasets: the taxi trajectory data, the restaurant data with food orders, and the cell tower data to simulate the distribution of users. Note that we simulate a sequence of food-delivery requests based on *Gaussian distribution* in advance which should arrive as a data stream in one day. The preliminary results are shown in Fig.2.

We compare the performance of proposed algorithms under different number of food-delivery requests. It is clear that the number of selected taxis grows gradually with the increasing number of food-delivery requests. Note that *FTBI*, *BTBI* and *BDBI* are baseline methods based on the construction algorithm, and LNS optimizes these baselines by *SR*. For example, *FTBI-SR* means that it selects the proper taxi for the request by *FT* and plans the route of the taxi to deliver the food by *BI*, then optimizes the solution by *SR*. We can find that LNS (i.e., *FTBI-SR*, *BTBI-SR* and *BDBI-SR*) can improve the initial solution to some extent. In addition, we investigate the number of selected taxis of six algorithms under the different time to deliver the food. In general, the peak hours of taxis to carry passengers during the day are about 12:00 and 18:00, which means that there are more available taxis visiting from restaurant areas to user areas. Therefore, the number of taxis to deliver the food at 12:00 is less than 11:30 and 18:00 is less than 17:30.



(a) Different number of requests (b) Different delivery time

Figure 2: Performance comparison under different situations.

4 CONCLUSIONS AND FUTURE WORK

In this paper, we presents a novel framework called FooDNet for food delivery by using existing resources of taxis, which can save the human resource, reduce the delivery cost, and improve the delivery efficiency. We also recognize some issues that are not reported in this work due to space and time constraints, which will be considered in our future work. First, we plan to solve the food delivery problem when there are few taxis running between the restaurant and user areas (e.g., infrequent-interaction areas), and taxis need to deliver the food specially without taking passengers. Second, we attempt to support real-time food delivery once users order the food based on the predicted movement of taxis and the predicted time of each restaurant for preparing the food. Third, we intend to make large-scale user studies over FooDNet, and test the performance of the system to solve the dynamic food-delivery requests. Finally, to apply our work in practice, it is important to study the complementary features and combination issues of the long-distance food delivery by FooDNet and the existing short-distance food delivery systems.

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