A CROWD SOURCING-BASED FOOD DELIVERY SYSTEM THAT IS EFFICIENT BY USING ALNS

[1]Dr. L Ravi Kumar, [2]Anil Kumar Gunda, [3]J Hymavathi, [4]Chennekki Ramu
[1,2,3]Assistant Professor, [4]Student, Dept. of Computer Science Engineering, Newton's Institute of Engineering, Macherla, Andhra Pradesh, India.

Abstract
This study employs geographic crowd sourcing to create the Food Delivery Network (FooDNet) (SC). It looks into how urban taxis enable the delivery of takeout food on demand. The delivery of food in FooDNet is more time-sensitive than in other SC-enabled service sharing systems (such as ridesharing), and the optimization challenge is more difficult due to the high-efficiency, massive quantity of delivery requirements. In our study, we focus on two on-demand food delivery issues that arise in many contexts: In the case of O-OTOD, where food is opportunistically delivered by taxis while they are transporting passengers, the optimization goal is to reduce the number of chosen taxis while maintaining a high incentive for the participating drivers; in the case of D-OTOD, where taxis are dedicated to delivering food only and do not transport passengers, the aim is to optimize the number of selected taxis (i.e., to raise the reward for each participant) and the total travelling distance to reduce the cost. A two-stage approach, including the construction algorithm and the Adaptive Large Neighborhood Search (ALNS) algorithmbased on simulated annealing, is proposed tosolve the problem.
Keywords – Task allocation, Spatial Crowd sourcing, Optimization.

INTRODUCTION

With the rise of the mobile Internet in recent years, a new service called online takeout ordering and delivery (OTOD) on smart phones has emerged (e.g. g., KFC delivery). In the OTOD service, the user may order takeout meals online and have it delivered by the restaurant employees. Additionally, new platforms like Seamless 1, Uber Eats 2, and ele. me 3 are being created as the new model of the OTOD service. The merchants that register in these platforms might pool the resources of professional delivery staffs to lower the cost, in contrast to the extra delivery technique where take-out food is brought individually by staffs of various restaurants. The OTOD service is often easy and time-saving, especially for those who are resting at home or busy working.

Though having rising development in the last few years, existing OTOD services still suffer some limitations. First, food deliveryis usually completed by using bicycles orelectric motorcars rather than cars in view ofthe delivery cost (e.g. g., ele.me), which decreases the delivery efficiency and results in the limited delivery range in geography because of the slow speed. Though the take take-out food is delivered by cars in some platforms (e.g. g., UberEats), the deliverycost is quite high for the requesters if they order the food frequently. Second, most foodorders appear in the same time period (e.g. g., lunch time or dinnertime), which resultsin a large number of delivery requests withina short time duration. Therefore, it becomes difficult to deliver food on time during the rush hour due to the limited number of delivery staffs. Merely expanding staff staffs may solve the problem on some point, but the resources of professional delivery staffs can be wasted as there are few food orders during most of the other moments of a day. Therefore, a new method is under investigated to tackle these challenges.

Spatial Crowd sourcing (SC) is an emerging paradigm that extends traditional crowd sourcing to the physical world, by assigning location location-based tasks to moving workers. It has been proved useful inquite a few application areas, such as environment monitoring and event sensing. Note that most of the existing studies on SC concentrate on object profiling/sensing, i.e., tasking individuals to perform the sensingtasks with their mobile devices. Other types of location-based tasks are not wellinvestigated. In this paper, we view OTOD as a special type of SC task, which refers to object delivery that delivers objects from oneplace (i.e., restaurants) to another place (i.e., the site of food requesters). Furthermore, we aim to extend and improve the OTOD service by leveraging SC.

Quite recently, there have been severalworks that try to combine SC and objectdelivery. Ridesharing is a typical applicationof object delivery among multiple passenger passengers based on SC. Specifically, a ridesharing system aims to plan a set of vehicle routes with minimum cost, andvehicles are capable of accommodating asmany passengers as possible. In addition to riding requests from travelers, there also might be delivery requests about goods, like parcels, which could share the resources of vehicle vehicles with people to utilize thevehicles resources sufficiently. For example,Crowd deliver is a novel system where packages share the resources of vehicles with passengers.

Inspired by previous studies, we devote to building a food delivery network that uses anabundance of taxis in the road network to deliver food based on SC. F For taxi drivers, extra income from the food delivery service can be obtained to lead to the long long-termengagement of drivers. 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. From the perspective of restaurants, delivering food using existing resources of urban taxis can decrease the cost on recruiting extra delivery staffs, and enable the long long-distance food delivery. Finally, from a city perspective, this networkhas a potential to relieve urban trafficcongestion by piggybacking new services (food delivery) on existing ones (passenger delivery).

To the best of our knowledge, this is the firstwork that studies efficient delivery network by sharing rides of passengers and food packages using taxis. Recently, there have been several studies on shared package package-passenger delivery. This is, however, quite different from shared food- passenger delivery as studied in this work. First, compared with average package delivery, food delivery has stricter "pick pick-up" (from the restaurant) and "arrival" (to the food requester) time constraints toensure the Quality of food and meet userdining 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 andlower the cost. These issues will result in a much more complicated optimizationproblem on de livery task assignment. Therefore, the solution of food delivery using SC needs to be further explored.

To address the above challenges, we proposeFooDNet, which is a novel Food Delivery Network that fulfills the OTOD service based on SC . In we solve the OTOD crowd sourcing problem by leveraging pervasive taxis running in cities. This paper significantly extends our previous work by considering different states of taxis, proposing the corresponding methods and conducting realistic experiments as well as evaluations . Specifically, we elaborate the design of FooDNet from the following two usage situations. The first one is that taxis with passengers deliver the food, named the Opportunistic OTOD Service (O -OTOD).Note that the priority o f passenger passengers is higher than food packages ,which means that the taxi should pick up all food packages before picking up the passenger, and deliver food after the passenger takes off. The second one is that taxis only deliver food packages, named the Dedicated OTOD Service (D-OTOD).

BACKGROUND WORK

Spatial Crowd sourcing

In recent years, by leveraging the power of ordinary people, crowd sourcing has become an efficient way to complete complex tasks. A lot of crowd sourcing applications have been developing d, such as image labeling and language translating. With the development of smart devices and mobile Internet, Spatial Crowd sourcing (SC) has become a new form of crowd sourcing that engages users to obtain the information with spatio-temporal features, such as environmentalsensing and traffic information mapping. Most of SC applications focus on mobilecrowd sensing (MCS) namely a crowd ofusers utilize their mobile phones to complete location-based tasks. In addition, there have been some SC platforms developed to effectively support human participation, like PRISM, and SPACESPACE-TA.

Object Delivery with Spatial Crowd sourcing

Based on the studies on SC, the object delivery problem with SC has attracted muchattention recently. Vehicle routing problem (VRP) with different constraints is a basic problem in object delivery. Pisinger et al. presented a new and general heuristic framework, denoted Adaptive Large Neighborhood Search (ALNS), which has been used to several variants of VRP in the present paper. Christiaens et al.

introduced a fresh ruin and recreate approach to solve capacitated VRP. In addition, a closely related problem to object delivery is the Dial-a-Ride Problem (DARP). Rahmani et al. formulated a heterogeneous DARP, and they proposed a column generation approachto generate feasible vehicle routes dynamically. Gschwind et al. provided a novel approach based on the ALNS to solve the DARP. Ma et al. developed a taxi- sharing system that can accept passengers" requests in real-time and schedule appropriate taxis. DARP arises in many practical application areas, for instance, combining taxi transportation and goods delivery can create attractive business opportunities. Li et al. considered conceptualand mathematical models in which people and parcels are handled in an integrated way by the same taxi network. Chen et al. proposed to exploit existing taxis that arecarrying passengers on the street to deliver packages collaboratively, which can simultaneously lower the cost and accelerate the speed.

PROPOSED WORK

We propose FooDNet, which is a novel system where the take-out food is delivered by taxis in the OTOD service by leveraging spatial crowd sourcing. Without loss of generality, we made the following assumptions to formulate the food delivery problem in FooDNet. First, taxi drivers are willing to accept the food delivery requests assigned by the system because they can obtain extra rewards. Second, the passenger is willing to wait for a relatively short time period cost on picking up food packages as we can give her/him discounts for share driding. Third, all the given food delivery requests in the FooDNet SC platform can be served because we have enough taxis in urban environments.

The proposed FooDNet framework is shown in Fig. 1.

Food ordering. The system has three stakeholders, namely restaurants, taxi drivers, and users. First, restaurants provide the relevant information for the system, including the location rl, the business hour rt and the food category rf. Meanwhile, the information of taxis is collected, i.e., the current location, the historical trajectories, and the passenger"s travel request denoted as pr(pl,pd,pt), including the current location pl, the destination pd, and pick-up time pt. When the user starts to order food inrestaurant r, she should provide her request information, including the location ul, thedelivery time period ut[uto,utd] (i.e., the order time uto and the deadline utd), and the kind of food rf. Finally, the food delivery request fr(rl,ul, [uto,utd],rf) is formed, whererl and ul represent the start and end points of the food order respectively.

Food-delivery request handling. After the user submits the food-delivery request, the system will determine whether to accept it. Based on the information of the restaurants and taxis, as well as the user"s request, the system will accept the food request fr if it satisfies the constraints. Particularly, if the user and the restaurant locate in frequent-interaction areas, it falls into the O-OTOD mode, and the constraint will rely on theorder time (e.g., the order time should be 30 minutes earlier than the delivery time, utd ≥uto+30). In addition, if the regions arewithin infrequent-interaction areas, the orderwill be handled under the D-OTOD mode,where both the order time and the taxis"income should be considered as constraints.

Delivery task allocation. The system willallocate accepted food-delivery tasks toproper taxis. The selection method is mainlydivided into two steps. First, we apply theheuristic algorithm to obtain the initialfeasible solution. Second, ALNS optimizesthe initial solution by removing and insertingrequests continually based on the localsearch framework. Finally, the optimizedsolution is obtained, i.e., the planned route ofeach selected taxi.

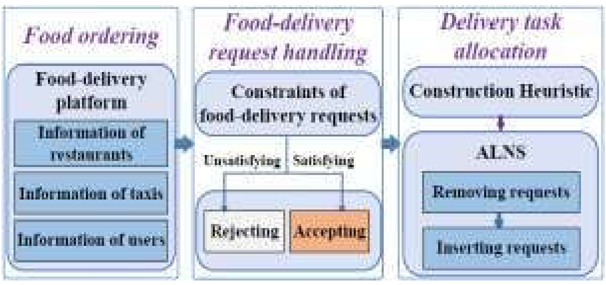

Fig. 1: An overview of FooDNet.

A. The Construction Algorithm

This section constructs the initial solution bythe heuristic algorithm. The heuristic algorithm in this paper simply selects theproper taxi for each food delivery request in view of all the food packages can be delivered on time. In addition, the routing planning problem should be considered todetermine the cost of taxis when selecting the taxi. For example, we can insert the locations of the food delivery request in the current route of the taxi to obtain the new route.

B. Adaptive Large Neighborhood Search(ALNS) Algorithms

This section describes the ALNS algorithm to optimize the initial solution obtained by the heuristic algorithm. The ALNS algorithmproposed in the paper is based on the ALNS heuristic described by Ropke et al., which is an extension of the LNS heuristic. In general, ALNS is a local search framework in which several competing removal and insertion heuristics are picked at random with adaptive selection probabilities to modify the current solution. Due to the diversity of large neighborhoods, ALNS will explore large parts of the solution space in a structured way. Compared to LNS, ALNShas the ability to get away from a local minimum based on the search framework,
e.g. g., simulated annealing and Tabu search.

Algorithm 1.
Adaptive Large Neighborhood Search(ALNS)

Input: Initial solution s, T, T_{max}, α
Output: Best solution s^*.

```
Initialize best solution s* ← s
while stopping criteria not met do
  j ← 0
  set μ_i, ε_i to 0
  while j < segment size do
    choose a destroy neighborhood N⁻
    choose a repair neighborhood N⁺
    generate a new solution s'
    if f(s') < f(s) then
      set s ← s'
    else
      set s ← s' with probability p=exp(-(f(s')-f(s))/T)
    if f(s) < f(s*) then
      set s* ← s, T_b ← T
    update μ_i, ε_i
    T ← α × T
    if T < 0.01 then
      T_b ← 2 × T_b, T ← min{T_b, T_max}
  update weights w_i
return s*
```

RESULT ANALYSIS

We study the results of proposed algorithms in terms of both the number of selected taxis and the total movement distance. In general, ALNS for D D-OTOD tries to optimize the solution in each iteration based on q requests. Therefore, we study the performance of ALNS under different value values of q controlled by the parameter φ. Inaddition, we analyze the income of drivers when they only deliver food, which is the main incentive to stimulate more users toparticipate in.

We compare the performance of proposedalgorithms under three data sets in Table 1, and each data set includes 200 food delivery requests. We can see that LNS can improve the bad solution obtained by the constructionalgorithm to some extent. In addition, theperformance of ALNS is superior in bothnumber of selected taxis and the totalmovement distance in comparison to the bestresult obtained by LNS.

TABLE 1

Performance Comparison of Different Algorithms For The D-OTOD Problem

	The number of taxis			Total distance (km)		
Data set	D1	D2	D3	D1	D2	D3
FTSI	110	100	117	1010	1158	1108
FTBI	22	37	54	188	336	491
BTSI	57	47	59	489	505	514
BTBI	21	26	39	148	198	317
BDSI	43	38	41	352	350	350
BDBI	14	18	31	106	134	266
FTSI-WR	48	36	49	393	348	416
FTBI-WR	20	30	35	123	261	296
BTSI-WR	37	30	38	224	215	238
BTBI-WR	20	22	33	148	164	263
BDSI-WR	32	26	29	209	163	179
BDBI-WR	**12**	**16**	28	74	133	236
FTSI-SR	47	35	47	401	352	399
FTBI-SR	19	28	34	159	296	313
BTSI-SR	35	30	37	213	213	252
BTBI-SR	20	21	32	148	198	317
BDSI-SR	32	26	29	206	162	179
BDBI-SR	**12**	**16**	**23**	76	133	158
ALNS	**10**	**11**	**10**	**61**	**81**	**73**

We discuss some issues that are not reported or addressed in this work due to space and time constraints, which will be considered inour future work.

Real -time food delivery. We attempt tosupport the real -time food delivery once users order food in our future work. Basedon the predicted movement of taxis and the predicted time for each restaurant preparing the food, the system can compute the food delivery time immediately once the user submit submits the food order.

Large-scale user study. In our work, wesolve the food delivery problem with a sequence of simulate simulated food delivery requests, while the system does not consider that the requests could appear randomly. Therefore, we intend to make large large-scale user studies over FooDNet, and test the performance of the system to solve the dynamic food-delivery requests, which will help identify practical issues and improve our system.

Incentive mechanism for taxi drivers. We just consider that the incentive of the taxi driver is proportional to the number of delivered food packages, which do does not take into account other factors. As for future work, we will define the incentive mechanism for the taxi driver in view of different situations, such as different timeperiods.

Practical applications. Food is delivered by taxis in FooDNet , which is be neficial to the long long-distance food delivery. However, it may not be a cost cost-effective way for taxis when delivering the short- distance food package packages. Therefore, to apply our work in practice, it is important to study the complementary features and combination issues between the long- distance food delivery by FooDNet and the existing short short-distance food delivery systems.

CONCLUSION

This study introduces a unique framework for food delivery called FooDNet that makes use of the existing cab resources to conserve human resources, lower delivery costs, and increase delivery effectiveness. We specifically suggest two problems: the OO- OTOD issue adds food delivery orders into the supplied taxi routes after they have been created to convey customers. In order to build the best taxi routes and timetables for a variety of food delivery requests with pickup and drop-off places, the DD-OTOD issue solely manages food delivery requests with taxis in idle load. Additionally, a two-stage approach is suggested to address the aforementioned issues, consisting of the construction algorithm and the ALNS algorithm.

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