A Queue Analytics System for Taxi Service Using Mobile Crowd Sensing

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Abstract

Passengers waiting queues and taxis waiting queues are commonly seen in many urban cities. Our poster presents a queue analytics system, which collaboratively uses the mobile data from taxis and smartphones, to detect both passenger queues and taxi queues. In particular, the system firstly determines the existence of taxi queues by analyzing the taxi data, and then make a soft inference on passenger queues. Meanwhile, the passenger side adopts the smartphone-based crowd sensing strategy to detect the personal-scale queuing activities. Lastly, the system aggregates the detection results and validates passenger queues. The extensive empirical experiments demonstrate our system can accurately and effectively achieve the design objectives. Moreover, the system envisions a novel crowd sensing way to perform online analysis using data from heterogeneous sources.

Author Keywords

Taxi Service; Queue Analytics; Mobile Crowd Sensing

ACM Classification Keywords

H.4.m [Information Systems Application]: Miscellaneous; H.3.5 [Information Storage and Retrieval]: Online Information Services

Introduction

In the densely populated cities, either passengers queuing for taxis or taxis queuing for passengers frequently occurs due to the citywide imbalance of taxi supply and demand. Timely and accurately detecting such waiting queues and the queue properties would undoubtedly benefit both public commuters and taxi drivers. We design a practical system detecting both passenger queues and taxi queues for taxi service, and deploy it in Singapore. The system collaboratively utilizes the crowd sensed mobile data from taxis and smartphones to conduct the queue analytics at each queue spot. On the taxi side, taxis periodically update their status, GPS location and instantaneous speed. On the smartphone side, a specifically designed application extracts the features from smartphone's sensor data to recognize the personal-scale queuing activities. Our backend cloud aggregates the information from both sides and derives the final queue analytics results.

There are some existing studies using a single source to detected a particular queue. For example, [1] uses taxi traces to capture the taxi queue, and [2] utilizes smartphone data to recognize the human queuing activity. Different from the previous work, our system collaboratively utilizes the data from heterogeneous sources, i.e., taxis and smartphones, to conduct queue analytics for both passenger queues and taxi queues. The extensive real world experiment results demonstrate the feasibility and accuracy of our system.

System Design

The system block diagram is illustrated in Figure 1, and it mainly consists of three subsystems: (a) taxi-side data collection subsystem; (b) cloud-side queue analytics subsystem; and (c) smartphone-side queue sensing subsystem.

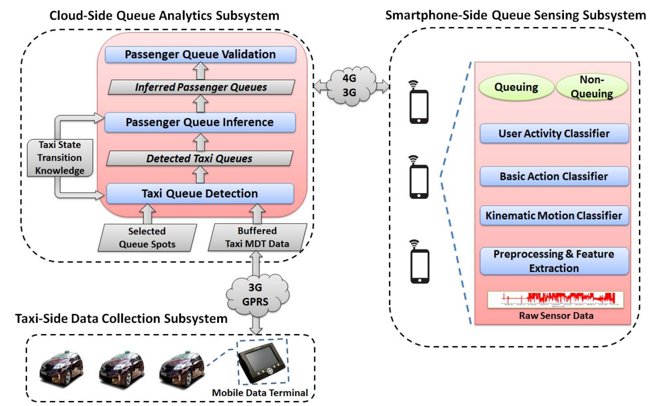

Figure 1: Block Diagram of the Queue Analytics System

Taxi-Side Data Collection Subsystem
By leveraging on a mobile data terminal (MDT) installed on each taxi, a total of 24000 taxis in Singapore keep updating their real-time status, e.g., FREE (available for passenger), POB (passenger on board) and ONCALL (booked by passenger), as well as their GPS locations and speeds. The latest taxi data would be instantly sent back to the cloud-side queue analytics subsystem. The data transmission mainly utilizes the cellular service (3G or GPRS), and the transmitted taxi data can be buffered at the cloud-side to further process.

Cloud-Side Queue Analytics Subsystem
The cloud-side queue analytics subsystem is the central component to utilize, coordinate and analyze the data collected from the taxis and the smartphones. It mainly consists of three modules:

- *Taxi Queue Detection Module*: the module mainly identifies the taxi queues at the given queue spots during the buffered period. More specifically, it firstly extracts the taxi pickup events from the buffered taxi data, and then associates the pickup events with the nearest queue spot. After that, it extracts the average taxi wait time and arrival rate to derive the average queue length during the buffered period. Finally, it determines the existence of a taxi queue.

- *Passenger Queue Inference Module*: the module makes a soft inference on the passenger queue at the given queue spot based on several criteria. For example, a considerable number of arrival taxis with a short average wait time (meanwhile no taxi queue detected at that queue spot) is an indicator of a passenger queue. The module provides the passenger queue's possible locations.
- *Passenger Queue Validation Module*: the module aggregates and processes the returned smartphone-side queue sensing results to validate the passenger queue existence. In most cases, a passenger queue can be validated if multiple smartphones report the queuing activities at the same queue spot.

Smartphone-Side Queue Sensing Subsystem
This subsystem adopts a crowd sensing strategy to conduct the personal-scale queuing detection on smartphones. More specifically, a lightweight application, which can be either actively enabled by the user or automatically enabled by the system, is installed on the smartphones. The application mainly performs the queueing recognition task based on the collected real-time accelerometer data, and uses three classifiers, namely kinematic motion classifier, basic action classifier and user activity classifier. Its basic workflow is illustrated in Figure 2 and the recognition results would be instantly sent back to the cloud-side queue analytics subsystem.

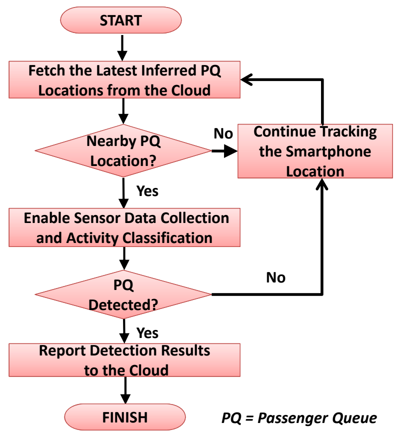

Figure 2: Queue Sensing Workflow on Smartphone

In short, the above described three subsystems work cooperatively and collectively to achieve the design objectives.

Empirical Evaluation and Discussion

We conducted the extensive experiments on both the taxi queue detection and passenger queue detection. The cloud-side server collects taxi data from 15000 Singapore taxis, and receives 8833 taxi messages every minute on average. The system currently sets the buffering duration to 15 minutes, and updates the buffered data every 5 minutes. A total of 171 queue spots, as illustrated in Figure 3, are used to conduct the queue analytics, and most are taxi stands in the business or shopping areas.

The experiment results show that among all the selected queue spots, 83.5% queue spots had taxi queue or

Figure 3: Queue Spots in Singapore

passenger queue. During the one month experiment period, 38.7% buffering durations are detected as taxi queuing time and 12.3% buffering durations are inferred as passenger queuing time. Figure 4 shows the daily variance of average taxi queue length at 10 busy queue spots on a working day (*solid line*). The ground truth is provided by an independent vehicle monitor system (*dash line*). The two curves match well and verify our taxi queue detection results.

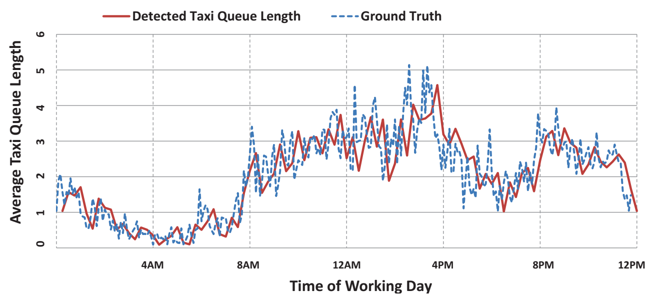

Figure 4: Average Taxi Queue Length in Working Days

Figure 5 demonstrates the detected taxi queue (TQ), the validated passenger queue (PQ) and the corresponding ground truth during a working day at a selected queue spot. The length of each rectangular in the figure represents the time span. We see that in general the detection results match well with the ground truth, while passenger queuing from around 5:20pm to 5:40pm was not validated. It is caused by all the queuing passengers do not have the queue sensing application on their smartphones during that short-term period.

On the smartphone side, the F1 score of the user activity classifier (queuing or non-queuing) is 0.82 and the total energy consumption of the queue sensing application is about 79 milliWatt.

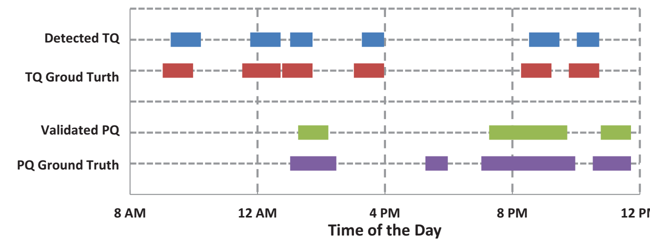

Figure 5: Queue Analytics Results and Ground Truth

Our future work includes improving the smartphone's queue sensing application for special queue spots, such as the taxi stands having waiting benches, and meanwhile promoting the deployment of the application among the frequent taxi riders. Moreover, we plan to introduce a new triggering mechanism that can actively activate the smartphone's application from the cloud side. Lastly, we would like to highlight that the main novelty of this work is to perform the online data analytics using the data crowd sensed from heterogeneous sources.

Acknowledgements

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