NURail Project NURail2012-UIC-R03

The final report for NURail project: NURail2012-UIC-R03 consists of two distinct documents. The first seven pages are titled “The Informed Railroad Traveler (Smartphone Application): Real-time Street Parking Availability Estimation” by Ouri Wolfson, Bo Xu, Leon Stenneth, Philip S. Yu and Jie Yang. The last five pages are a report titled “The Informed Railroad Traveler (Smartphone Application): RSVP: Ride-Sharing via Virtual-Pools (Multimodal Ridesharing)” by Ouri Wolfson, Jane Lin, Sandeep Sasidharan and Sol Ma.

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National University Rail Center - NURail
US DOT OST-R Tier 1 University Transportation Center

NURail Project ID: NURail2012-UIC-R03-A

The Informed Railroad Traveler (Smartphone Application)

Real-time Street Parking Availability Estimation

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DISCLAIMER

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TECHNICAL SUMMARY

Title

Real-time Street Parking Availability Estimation

Introduction

Real-time parking availability information is important in urban areas, and if available could reduce congestion, pollution, and gas consumption. This project presents a software solution called PhonePark for detecting the availability of on-street parking spaces. The solution does not rely on any dedicated infrastructure or external sensors, and therefore is much more economical than existing solutions. For any driver carrying a mobile device with GPS and/or accelerometer, PhonePark can automatically determine when and where she parked her car. The proposed technology does not rely only on GPS/accelerometer for parking activity detection, instead Bluetooth enabled mobile devices can also be utilized. Parking activities can also be detected by taking advantage of pay-by-phone parking. Further contributions include an algorithm to compute the historical parking availability profile for an arbitrary street block and algorithms to estimate the parking availability in real-time for a given street block. The algorithms are evaluated using real-time and real world street parking data.

Approach and Methodology

This project proposes a software solution, called PhonePark, which detects on-street parking availability using mobile phones carried by the drivers. In the PhonePark solution, for parking detection using the GPS/accelerometer, we follow the general principle of sensor fusion and classification that is used for context detection or activity recognition. First, from training data, we build a transportation mode classification model in terms of mobility patterns. Then, when parking is to be determined, sensor inputs are fed to the already trained classification model. Finally, certain transportation mode state transitions are detected. For example, for street parking, the following transportation mode transitions are expected to be observed: *car → stationary → walking*. Based on this transition pattern (i.e., *car → stationary → walking*), we may infer that the driver parked at the stationary point.

For parking detection via Bluetooth, the pairing connection between the driver's mobile phone and the car's on-board Bluetooth is considered. This relies on the fact that nowadays more and more cars have in-vehicle Bluetooth functionalities. In this work, parking activities can also be detected by pay-by-phone piggyback.

The project also introduce an algorithm to construct the *historical availability profile* (HAP) for a street block. This algorithm computes estimated values for the mean and the variance of parking availability for an arbitrary street block.

In addition to the HAP construction algorithm, we also introduce other algorithms that can estimate the real-time parking availability on a street block. These real-time estimation algorithms are called *parking availability estimation* (PAE) algorithms and they utilize different combinations of the historical parking availability and real-time observations to estimate the current street parking availability.

Findings

This project makes the following scientific contributions:

1. Algorithms to detect the status of street parking slots. These include parking/deparking detection by transportation mode transitions, Bluetooth pairing, and parking pay-by-phone piggyback,
2. An algorithm that can construct the historical availability profile (i.e., mean and variance of parking) for a given street block,
3. Algorithms for estimating in real-time the current parking availability on a street block,
4. Experimental evaluation of the algorithms using actual real-time street parking data from SFPark.org, and
5. Theoretical underpinnings of the proposed techniques.

Conclusions

In this paper, parking status detection, historical parking profile construction, and parking estimation algorithms are proposed. The algorithms are validated using real-time and real world parking availability data. For parking status detection, we propose a cost effective solution that utilizes mobile phone sensors such as GPS, accelerometer, and Bluetooth sensors. Furthermore, the parking status detection algorithm may piggy back on pay-by-phone for parking transactions.

Given the fact that not all drivers carry a mobile phone and the fact that not all drivers with a mobile phone have the PhonePark system installed, the penetration ratio of the PhonePark system may not be 100%. Additionally, PhonePark may produce false observations of parking activities due to GPS errors, transportation mode detection errors, and Bluetooth pairing errors. The parking availability estimation algorithms take these limitations into consideration and then provide a final estimate on the availability of street parking spaces.

Specifically, parking availability estimation (PAE) algorithms estimate the street parking availability in real-time by combining historical parking statistics with real-time parking observations. Several approaches on combining historical parking statistics with real-time parking observations are considered. Experimental and theoretical analysis demonstrate the effectiveness of the parking availability estimation algorithms.

In general, the proposed approach is economical, convenient, and flexible. It produces good estimation in real-time on the availability of street parking spaces. The estimation of parking availability has potential to improve drivers' parking experience by saving parking search time, reducing gas consumption and CO_2 emission.

Recommendations

Several approaches on combining historical parking statistics with real-time parking observations are considered. Experimental and theoretical analysis demonstrate the effectiveness of the parking availability estimation algorithms. Specifically, for penetration ratios of 1%, the average error of street parking availability estimation is below 2. More studies show that the combination of historical parking statistics and real-time parking observations as done in weighted average (WA) and Kalman Filter (KF) is more effective than using solely historical parking statistics (HS) or solely real time observations (SPP).

Publications

B. Xu, O. Wolfson, J. Yang, L. Stenneth, P. Yu, P. Nelson, "Real Time Street Parking Availability Estimation", Proceedings of the 14th International Conference on Mobile Data Management (MDM), Milan, Italy, June 2013.

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The Informed Railroad Traveler (Smartphone Application)

RSVP: Ride-Sharing via Virtual-Pools (Multimodal Ridesharing)

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TECHNICAL SUMMARY

Title

RSVP: Ride-Sharing via Virtual Pools

Introduction

Getting a taxi in highly congested areas (e.g. train stations, airports, conferences) is both time consuming and expensive. In this project, we propose RSVP, a virtual-pool based ridesharing system for transport hubs, such as airports, railway stations, etc. In these places, a steady stream of passengers arrive via some public transport mode, say train, and then depart to different destinations. The large volume and continuous flow of arriving passengers create a golden opportunity for ridesharing among departing passengers. While the emergence of novel Transportation Network Companies (e.g. Uber) has helped increase the supply of drivers during peak times, they have done little to reduce congestion in 'hot spots' such as airports, major stations, and stadiums. Creative on-demand transit service is needed more than ever in the post-Uber era to address congestion at 'hot spots', to accommodate the modern traveler and to capture the benefits of the smartphone revolution. The goal is to devise ridesharing algorithms for RSVP and evaluate them using a database that recorded real taxi trips from a transport hub.

Approach and Methodology

In this project, we propose a virtual-pool based ridesharing system for transport hubs, such as train stations. The RSVP scheme combines in a unique way three existing mechanisms: virtual queues, slugging (i.e. walking for the purpose of ride-sharing), and multiple-drop-off ride-sharing. For example, upon arriving at the train station, a passenger expresses interest in taxi-ridesharing by specifying her trip and electronically enrolling it into a time pool, e.g. the 11:00-11:05 pool. The trip specification indicates the destination, and the bounds on walking and delay times that the passenger is willing to tolerate in ride-sharing. Once the pool closes, say, one minute before its start-time, or when it is full, whichever occurs first with *n* trips in the pool, a MatchMaking (MM) algorithm is run on these *n* trips, creating a smaller set of *m* merged trips, each of which will be served by a single taxi. Each merged trip may consist of multiple drop-off points of the ride-sharing passengers. The selection of drop-off points will satisfy the walking and delay time constraints specified by the passengers.

Findings

Our proposed scheme differs from existing taxi ridesharing techniques in two aspects. First it applies the virtual queue concept in transport hotspots to create ride-sharing pools and efficiently manage the ride-sharing demand. Second it considers SLuggIng-Multiple-drop-off (SLIM), a hybrid form of ride-sharing that combines slugging and multiple-drop-off ride-sharing. In this work we formally prove that this increases the ride-sharing opportunities.

The contributions of this paper are:

1. We formalize the SLuggIng-Multiple-dropoffs (SLIM) ridesharing problem and mathematically prove that some trips are shareable only if they allow slugging.
2. We propose efficient algorithms, including a performance-improvement technique based on Euclidean filtering, for producing a SLIM ride-sharing plan on a virtual pool.
3. We evaluate the scheme with a database of real taxi trips in NYC, and demonstrate that it produces savings of 25-40% in terms of the total number of trips.
4. We quantify the benefits of adding walking to multiple-drop-off ride-sharing

Conclusions

In this paper we proposed the RSVP scheme to facilitate ride-sharing at transportation hubs. The scheme combines in a unique way three existing mechanisms: virtual queues, slugging, and multiple-drop-off ridesharing. The scheme produces pools of trips, which are then consolidated into ride-sharing plans by the MatchMaking (MM) system. Technically, the heart and novelty of the MM system is a combination of two components: (1) Euclidean filtering that uses Euclidean geometry to reduce the complexity of finding an optimal ride-sharing plan, and (2) the Pairwise Shareability Test (PST) algorithm which uses a middle ground between single-source-shortest-path and all-pairs-shortest-path.

Then we evaluated the RSVP scheme on 100 random pools formed from 1.8 Million trips that originated from LaGuardia Airport in NYC. The results indicate that:

(1) The trip-savings enabled by RSVP-ride-sharing are significant, e.g., about 25% of the trips are saved if about 75% of the passengers are willing to ride-share. This is true for a modest delay of 10% of the trip time, and a maximum walk of 5 minutes.

(2) Walking is valuable in combination with multiple-drop-off ride-sharing. For example, if passengers allow a 10-minute walk, then the trips-reduction by ride-sharing increases from about 10% to about 30%. Considering that at passengers often walk for 10 minutes from the gate to the curb, this assumption seems reasonable.

(3) The computation time for a 6 minutes pool of trips is less than 1 minute.

(4) Euclidean filtering technique employed is effective, reducing the computation time by 30%-50%.

Recommendations

The results obtained in this research project demonstrated the benefits of ride-sharing via virtual pools in major transport hubs such as train stations. The scheme permits remote check in and eliminates the need of standing in a physical line and are incentivized to rideshare.

Publications

This study is accepted as a regular paper in 17th IEEE International Conference on Mobile Data Management (MDM 2016). The paper is structured as follows. Section I provides an introduction. Section II reviews relevant work. The model of multimodal ridesharing is introduced in Section III, and present the MM system and algorithms the virtual queueing system in Section VI. We evaluate it in Section V. In Section VI we conclude and discuss future work.

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