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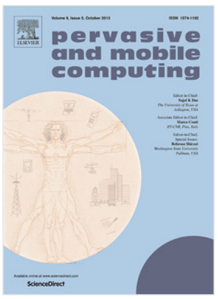

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Unlocking the Smartphone's Sensors for Smart City Parking☆

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Abstract

Studies have shown that drivers often spend over 20 min cruising for parking in city centers, accounting for as much as 30% of the traffic congestion. In response, cities like San Francisco have deployed systems capable of providing drivers real-time parking availability information. However, such systems rely on specialized infrastructure whose installation and maintenance costs in the tens of millions of dollars, unaffordable for many cities.

We present SmartPark, a system for real-time parking information that relaxes the requirement for specialized infrastructure, relying instead on the smartphone's sensors and the ubiquitous Wi-Fi and cellular infrastructure. To accomplish this, SmartPark addresses two major challenges, under the constraint of minimum impact on battery life: transportation mode detection and location matching. To minimize initial deployment cost and risk, SmartPark introduces an analytical approach for estimating parking availability even when only a small fraction of users adopt the application. We evaluate SmartPark using simulations and in the wild. Simulation results show that SmartPark, benefiting from as little as 20% adoption rate, can estimate parking availability with accuracy above 90%. Experimental results with the help of 12 volunteers show that SmartPark detects unparking events 97% of the time while triggering zero false positives.

1. Introduction

Someone named Bob is cruising around downtown looking for a place to park. Using an application on his smartphone, he identifies a free spot in the next block, saving him valuable time. Indeed, a Parsons Brinckerhoff study [2] of New York City's Chinatown showed that on weekends 41% of drivers spend more than 20 minutes looking for on-street parking. This figure increases to 54% on weekdays. Using this application also reduces Bob's carbon footprint – in congested urban areas 30% of the traffic is due to drivers cruising for a parking space [3, 4]. Once parked, Bob leaves the vehicle and goes about his business. The application keeps track of his movement and can detect automatically when he returns to the vehicle and pulls out of the parking space. It computes the time Bob spent parking, charges his account and then marks the respective parking spot as available again. This saves Bob the inconvenience of having to anticipate how long he will be away, go to the ticket machine to pay, and then place the receipt on the dashboard. At the same time, it saves the city a significant amount of money. Cincinnati, for example, is owed about $12 million from unpaid parking tickets dating back to 2005 [5]. What is more, as the application relies on the smartphone's sensors and infrastructure already available, cities will not have to invest in building and maintaining an extensive parking payment infrastructure. Finally, the application has a negligible effect on the battery.

Unfortunately, despite some efforts [6], no such application has gained wide adoption. The reason is twofold: First, providing real-time parking availability information requires knowing in real-time when a user vacates a parking space[1]. However, automatically identifying an unparking event with almost 100% accuracy while relying on smartphone sensors remains an open problem. Second, such an application needs a broad user base to be successful and requiring a city-wide roll-out of a smartphone application creates a high barrier to entry. The SF-Park pilot project [7] addresses both challenges by installing dedicated in-ground parking sensors on approximately 7000 on-street parking spaces. This required $18 million as start-up cost, or roughly $2500 per space [8] – a prohibitive cost for many cities. One might be tempted to think that users should just notify when vacating a parking space. However, the Google Open Spot experiment has shown that most users neglect to inform the system when they vacate a parking space [9]. Smartphone solutions based on GPS have been proposed to automatically detect unparking events [10, 11, 12] and shown to be accurate. However, relying on GPS can quickly drain the battery, a non-starter for most smartphone users.

☆An early version of this work appeared in the Proc. of IEEE ICC 2016 [1].

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[1] A user selects on the application a parking space among those available, making the problem of knowing when a place is occupied trivial. Dealing with malicious behavior, a user selecting a place but parking at another, is left as future work.