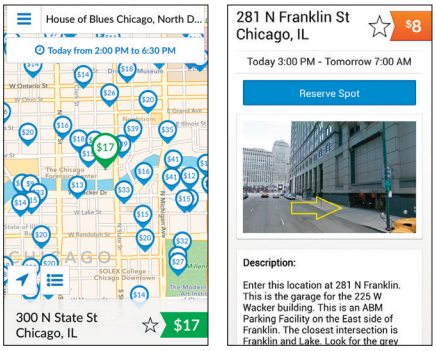
Technology | DOI:10.1145/2754954 Samuel Greengard

Between the Lines

Smartphone apps are driving changes in the way people park. Sensors, crowdsourcing, and big data are making it easier to find open parking spots.

It is no secret that one of life's thorniest and most frustrating challenges revolves around finding a parking spot. Every day, in a scenario that plays out in urban areas around the world, motorists cruise, circle, and dart through streets in search of an elusive place to stow their vehicle for a few minutes or a few hours. Too often, parking lots are full and street spaces are next to impossible to find. The process is incredibly inefficient and time-consuming—and it frays nerves and burns gasoline.

University of California, Los Angeles (UCLA) distinguished urban planning professor Donald Shoup has estimated motorists searching for street-side parking spots in Los Angeles accrue 950,000 excess vehicle miles per 15-block area over the course of a year. This extra driving—which accounts for about 30% of traffic in business districts—consumes approximately 47,000 gallons of gas and generates about 730 tons of carbon dioxide annually. However, those factors are only parts of the problem. Many people overpay for metered parking in order to avoid costly fines. "The simplest, cheapest, and fairest way to reduce traffic congestion is to set the right prices for on-street parking," Shoup says.



SpotHero

The biggest problem with parking apps, for now, is simply attracting enough users to make the apps valuable.

"It's an incredibly inefficient system," says Geoffrey Challen, an assistant professor at the State University of New York at Buffalo (SUNY Buffalo).

However, all of this may soon change. Smartphones, apps, big data, and increasingly sophisticated algorithms are introducing new ways to address everything from the probability of finding a parking spot at any given moment to pocketsourcing methods that gauge the actions and behavior of motorists. Although researchers and private companies are approaching the task in fundamentally different ways, the common denominator is that it may soon be a lot easier to hop in a car, drive to a destination, and find an available parking spot there.

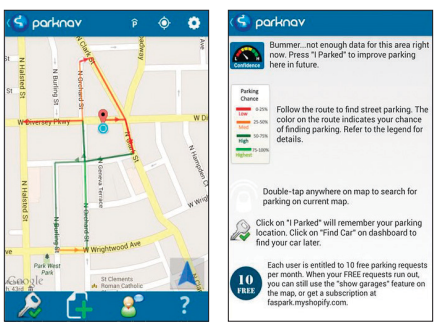
"Mobile technology and sensors are fundamentally changing the equation," explains Eyal Amir, a professor at the University of Illinois at Urbana-Champaign and CEO of Incube, Inc., a firm that collects street-level information and uses it to recommend driving routes and parking options through an app called Parknav. "With the availability of big data, we are able to understand and address parking in a fundamentally different and better way. We are able to introduce efficiencies that weren't possible in the past."

On the Spot

As cities and individuals look for ways to reduce congestion, save fuel and time, and improve access to shops and other businesses, parking is clearly in the crosshairs. For example, in Portland, OR, sensors in parking structures at Portland International Airport detect whether vehicles occupy spots. A red light above a space indicates it is taken, and a green light suggests the spot is available. At the end of each row, signs display available spaces. These same systems have been used in Europe and other locations for years.

In other instances, lots and apps now book reservations or auction off parking spots, though some cities, including Los Angeles and San Francisco, have attempted to shut down these services, particularly when they involve private parties holding and auctioning off public spots and spaces. Some app operators have attempted to pay individuals to grab spots on the street, hold them and then auction them off, often for $4 to $5.

Trying to make sense of parking and understand where and when spots might be available is no simple thing. The task is typically based on a combination of three elements: sensing or crowdsourcing, understanding human behavior, and accumulating massive data that is constantly undergoing change based on both



ParkNav

predictable (holidays) and unpredictable (weather) events. Says Cecilia Mascolo, professor of mobile systems at the University of Cambridge in the U.K., "This is all about how you can use sensors to better understand human behavior. People respond to parking challenges in very personal and specific ways, but there are overall patterns."

Amir says the introduction of the iPhone, and then Android smartphones, changed the stakes. Most importantly, they introduced a platform for connecting people into a broad human network and using common apps and interfaces to collect, manage, and apply data. The ability to carry them in pocket or purse—and create a persistent connection—was revolutionary. Meanwhile, smartphones have advanced radically over the last eight years. Sensors and increasingly powerful processors—along with crowdsourcing, big data, cloud computing, and artificial intelligence—have made it possible to detect and decipher parking patterns in ways that once would have been unimaginable.

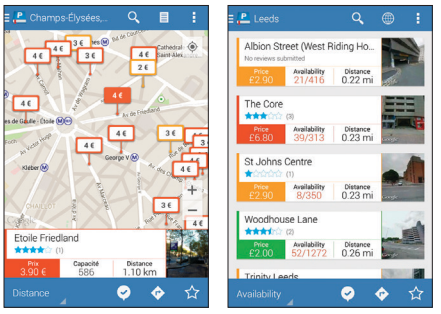
Over the last few years, a spate of parking services and apps has appeared.

Some, such as Pango Mobile Parking, allow users to pay for street parking or spaces at private lots using their smartphones. The service is live in more than 60 cities worldwide.

Others services, such as ParkingSpotter, BestParking, Parkopedia, SpotHero, and ParkMe, help users find and reserve spots through a website or mobile app. Typically, these services display a map with pins displaying current prices. In many cases, these apps require cooperation with parking facilities or government agencies. They often rely on magnetic loops and Wi-Fi to count vehicles and transmit data.

Pango

While these services may make it easier for some people to park some of the time, they do little to address overall load demand and the inevitable parking crush that hits cities during business hours and at other peak times. They also do not help individuals find specific spots. This has led researchers, including Challen, Amir, and Mascolo to dig deeper into the parking challenge and look for ways to reduce the need to circle blocks or structures searching for a coveted spot. Yet even with sophisticated sensors, algorithms, and APIs to move data between systems, this is an incredibly challenging task.



Parkopedia

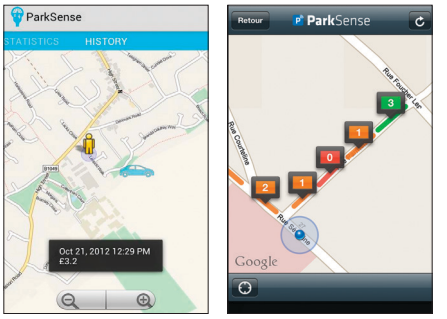
Forward Thinking

Most researchers and app developers aim to make it easier to find a parking spot while avoiding expensive technology and infrastructure upgrades.

Challen and a team at SUNY Buffalo have explored the concept of pocketsourcing by developing an Android-based app. It relies on GPS and accelerometer data from smartphones to record locations and movements of participants. There are no technology investments or upgrades for lots, and users do not have to click any buttons. The app sends data to a server, which plugs in data from OpenStreetMap; the aggregated data reveals the odds that a space is available at a particular location.

The system makes inferences about user activity based on specific movement characteristics. It can differentiate walking from the motion of a vehicle and even can identify different speed and movement patterns for cars. Challen's team tapped 105 smartphones around Buffalo, NY, and, over a 45-day span, studied more than 10,800 arrivals and departures using a camera to verify the accuracy of the algorithm. They found they could predict the availability of parking spots at about a 94% accuracy rate.

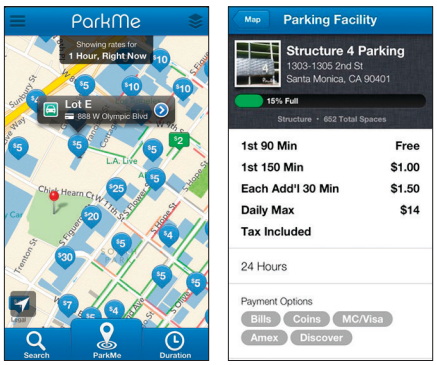
At the University of Cambridge, Mascolo has focused her research on street parking. "People have trouble finding places to park, they overpay, and they wind up getting fined," she says. The team developed a smartphone-based sensing system that taps into accelerometers and gyroscopes on the phone as well as surrounding Wi-Fi beacons to sense when people leave parking spots. Using a Wi-Fi signature-matching approach that compares the phone and the beacons, it is possible to detect when a driver returns to a parked vehicle and begins driving. "We know the Wi-Fi stations around the vehicle and that creates a specific fingerprint of the place," she says. The system, called ParkSense, not only identifies when a spot becomes available, it introduces a pricing model based on actual usage. She studied 484 drivers and found the system reduced driving time by 15%.



ParkSense

While Challen and Mascolo have studied parking and conducted academic research on the topic, Amir has started a commercial company named AI Incube Inc. and developed an app that aids in finding parking spots. The firm's Parknav app works in Chicago, San Francisco, Munich, and Hanover. It continually collects data about motorists as they move in and out of parking spots and constantly updates the underlying algorithm through machine learning, rather than traditional statistical methods. This not only helps refine the algorithm dynamically as data flows in, but it also detects variations based on the day of the week, holidays, or when sporting events take place.

Gigabytes of data per day flow into the system, which adjusts dynamically



ParkMe

using real-time GPS data along with proprietary and public data sources in order to become more accurate over time. The company claims the system reduces street parking time by 70% or more. ParkNav, which offers iPhone and Android apps for free (it currently boasts about 120,000 users), makes money by selling data to the automotive industry, companies that operate fleets of vehicles, and large real estate firms looking to optimize vehicle fleets. The data consumers generate when they use the app might also benefit governments, particularly cities, Amir says. "It has the potential to redefine the way we approach parking and introduce far more efficient systems."

Driving Progress

The biggest problem with parking apps, for now, is simply attracting enough users to make the apps valuable. Almost all plug-in data comes from a relatively small percentage of motorists. As Amir puts it, "If you have 95% of the population using an app, you can generate extremely accurate data. If you have only 33% using the app, you have data from one [vehicle] but you are missing the other two [vehicles]. As a result, you have to play more games with the data. You have to use more hints—about the desirability of a parking spot or popularity of a particular lot—and make more projections." A problem with making assumptions, Amir says, is that people do not behave consistently or in a predictable way.

In addition, even the best sensors and algorithms can be fooled. For example, a passenger in a vehicle may access the same app the driver is using; in that instance, the system may detect two cars pulling away from a spot rather than one. That, in turn, introduces another problem. "Crowdsourcing and pocketsourcing are extremely powerful tools," Challen says, "but the more you ask users to do, the less they participate and the more prone they are to forgetting or ignoring requests for data input. They may also be a couple hundred feet away or it may be a few minutes later, and a parking spot is already taken."

Nevertheless, parking apps are rolling forward and growing in appeal. Researchers say that within the next decade, they will play a crucial role in finding parking spots and reducing urban congestion. They may also introduce fairer parking pricing models that are based on actual time used rather than pre-paid blocks of time. As Shoup puts it, "The recent flowering of technology to measure on-street parking occupancy and to charge variable prices for on-street parking now allows cities to set these right prices."

Says Amir: "The key is to get people to understand the value of the technology and get major companies like Google to embed it into mapping apps and other tools so that it can be used in a more intuitive and useful way." C

Further Reading

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Samuel Greengard is an author and journalist based in West Linn, OR.

Milestones

HiPEAC Unveils 5th Vision Document

The European Network of Excellence on High Performance and Embedded Architecture and Compilation known as HiPEAC (High Performance and Embedded Architecture and Compilation) recently released its fifth HiPEAC Vision document (http://bit.ly/1wyXYu5) presenting recommendations for Horizon 2020, the European Union's 80-billion-euro Research and Innovation program for 2014–2020.

The mission of the HiPEAC network, which includes "about 1,500 researchers in computing systems in Europe," according to the organization's website, www.hipeac.org, is "to steer and increase the European research in the area of high-performance and embedded computing systems, and stimulate cooperation between academia and industry and computer architects and tool builders."

The network is run by a consortium of six universities, one research institute, and five companies, and is coordinated by Belgium's Ghent University.

The organization says recommendations in its latest Vision document are "based on an analysis of market trends, a discussion of technology constraints and opportunities, and a review of Europe's strengths and weaknesses in the field of computing systems."

Marc Duranton, chief editor of the Vision document, said its key theme "is the imminent end of uninterrupted exponential growth in computation, communication, and storage capacity with potentially disruptive consequences for the global economy."

HiPEAC network coordinator Koen De Bosschere, a professor at Ghent University, called the Vision document "one of the key documents steering the research funding in computing systems in Europe.

"We believe it is definitely important for the ACM Europe community, but also relevant for the global ACM community."

—Lawrence M. Fisher