ParkNet

Drive-by Sensing of Road-Side Parking Statistics

Paul Ksiazek
What is ParkNet?

• ParkNet is a mobile system comprising vehicles that collect parking space occupancy information while driving by.
Motivation

- Challenging to obtain real-time street-parking availability statistics.
- Traffic congestion is costly.
  - costs billions of dollars in the United States alone
- Congestion and delays are largely due to parking.
- No data available for roadside parking.
Usages

- Improve traveler decisions
  - suggest parking spaces.
- Dynamic parking space pricing
  - price changes based on slots available.
- Assist parking enforcement
Setup

Each car gathering data has the following:

- **Ultrasonic Sensor**
  - distance to car
  - availability increasing
  - potential for reuse

- **PS3 webcam**
  - evaluation, analysis and training

- **GPS**
  - coordinates of car

- **Computer, power adapter, and wiring**
  - compute and transmit data
Setup

- The system is installed into vehicles which regularly move about the city.
  - taxi cabs (used in this paper)
  - public buses
  - police cars
- Easier to install and users don’t have to worry about setting it up themselves.
Slotted vs. Unslotted

- **Slotted**
  - fixed size
  - one car per slot

- **Unslotted**
  - depends on vehicle length
  - fire hydrants, no parking
Goals

- Determine parking availability on an hourly basis.
- Helpful to parking enforcement.
- Low-cost.
- Low vehicle participation.
Slotted Algorithm

Width: distance from the start to the end of a dip. Depth: how far from the baseline a dip extends.

- Remove dips with too few readings.
  - can be caused by going too fast
- Training
  - get ideal threshold values
  - 19 separate test trips
  - optimal error rate of 12.4%
- Depth threshold
- Width threshold
  - width greater than 2 thresholds counts as 2 cars.
- Vacant Spaces = total slots – counted cars
Unslotted Algorithm

- Measure space between parked cars.
- See how many cars can fit in that space.
  - 6 meters per car
- Available spots = distance / fixed size (6 meters)
Evaluation

• Used webcam pictures to evaluate accuracy.
  – False positives: trees, pedestrians, bikes.
  – Misdetection: car is there but not detected.
• 95% accuracy for parking space counts.
• 90% accuracy for occupancy maps.
GPS Inaccuracy

• Accuracy for occupancy map must be higher than space count.
• GPS inaccuracy can cause spots to be mismatched.
• Used environmental fingerprinting to increase accuracy.
  – fixed objects are location-tagged using the video stills.
  – street needs to be traced multiple times so fingerprinting takes more effort.
• Position corrected using the Hungarian algorithm.
  – graph optimization algorithm.
GPS Inaccuracy

![Graph showing percentage errors with and without fingerprinting](image)

- Overall: 19.6% (Uncorrected), 8.8% (With fingerprinting)
- False positives: 13.5% (Uncorrected), 4.5% (With fingerprinting)
- Miss detections: 6.1% (Uncorrected), 4.3% (With fingerprinting)
Mobility and Scalability

• Tracked mobility patterns of 536 taxis in San Francisco over a month.
• Greater San Francisco area  
  – mean time between visits in hundreds of minutes.
• Downtown  
  – mean time less than 10 minutes.
• Most parking is in areas with many taxis.
ParkNet vs Fixed Parking

Fixed Parking: monitor each slotted parking space individually.

• SFPark
  – 6000 parking spaces
  – currently being employed in San Francisco
Cost

• ~$400 for each sensing vehicle.
  – $250-$800 for the smart parking system
• ~$120,000 for a given area in San Francisco.
  – $1.5 million for the smart parking system.
• One vehicle can cover multiple parking spots.
  – Need a sensor for each fixed parking spot.
Maintenance

- ParkNet is easy to maintain,
  - can be maintained when taxis go in for maintenance.
  - cities offer many free WiFi spots.
- Each fixed parking spot must be maintained separately.
Disadvantages

- Parking spot is not guaranteed to be up to date.
  - fixed parking sensors are always up to date.
- Greater coverage, but random.
Unresolved Issues

• **Multilane Roads**
  – only tested on single lane roads.
  – car driving next to sensing vehicle.

• **Speed Limitations**
  – high speed leads to misdetections.
  – parking areas usually have lower speed limits.

• **Obtaining maps**
  – time-dependent spots
  – manual construction from satellite pictures
  – possible to automatically generate
Related Works

• Parking garages with counters.
  – not displayed on the internet.
• Airports and train stations
• Buying and selling parking spaces.
• Reserved parking spaces.
• Pothole detection.
Results and Contributions

• Their prototype was a success in obtaining real-time street-parking statistics.
  – Accurate
  – Low Cost
  – Scalable
  – Useful

• Useful even with a slight error rate.
  – don’t need to know exact number of available slots.
Future Work

• Use the webcam as part of the system.
  – computer vision algorithms can help detect cars.
  – solution to lane detection?
  – give users images of the parking spaces.

• Prediction based on statistics.
  – data gathered over time can be used to predict parking space availability in the future.
  – useful for long-term planning.