ParkNet: Drive-by Sensing of Road-side Parking Statistics

Published by: Mathur, Suhas, Tong Jin, Nikhil Kasturirangan, Janani Chandrasekaran, Wenzhi Xue, Marco Gruteser, and Wade Trappe in Mobisys 2010.

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Part of these slides are reused from:
http://www.eecs.ucf.edu/~turgut/COURSES/EEL6788_AWN_Spr11/Lectures/ParkNet.ppt
Motivation

- 3.5 to 14 minute cruising time per trip [2]
- 30% traffic congestion by drivers cruising parking [2]
- E.g. Westwood Village creates 950,000 + VMT, 95,000+ hours and 47,000 gallons of gasoline wasted, and produces 730 tons of CO2 [3]
Parking availability detection

- Human report and dedicated sensors (high cost)
- Image based classification (customized for each facility)

People are still in lack of parking information!!
Introduction - ParkNet

• Drive-by Parking Monitoring
  – Uses ultrasonic sensor attached to the side of cars
  – Uses GPS to track the real-time location
  – Detects parked cars and vacant spaces

• Attaches to vehicles that comb through a city
  – Low cost
  – Low penetration
ParkNet Architecture

- Space count (most parking applications)
- Occupancy Map (parking enforcement)
Prototype Development

• Moxbotix WR1 rangefinder
  – Emits every 50ms
  – 12-255 inches

• PS3 Eye webcam
  – 20 fps
  – Used for ground truth

• Garmin GPS
  – Readings come at 5Hz
  – Errors can be less than 3m

• On-board PC
Challenges

• Ultrasonic sensor does not have a perfectly narrow-width
  – False Positive: Trees, people, recycling bins
  – False Negative: missed a parked vehicles

• GPS Errors
  – Mis-match a detected car to a wrong spot
Prototype Deployment

- 3 vehicles
- 3 specific areas
- 2 month period
- 500 miles
- All range sensor data is tagged with:
  - Kernel-time,
  - range,
  - latitude, longitude,
  - speed
Parked Vehicle Detection - Dips

• “dip”: a change in the rangefinder readings which usually occurs when there is an object in view

Two Cars Parked Together
Parked Vehicle Classifier

- Sensor trace (width and depth) measured against a threshold to determine if a “dip” is a parked car.
- Threshold established from training data
  - 2.52 meters width
  - 89.7 inches
- Error rate: 12.4%
Parking Availability Detection Algorithms

• Slotted Model
  – Determines the dips classified as cars
  – Subtracts the # of cars from the # of spaces in the area

• Un-slotted Model
  – Determines which dips are classified as cars
  – Measures the distance between dips to see if it is large enough to fit a car

• Training
  – 20% of the data is used for training
  – 80% of the data is used for evaluating performance
Parking Availability Detection - Slotted

- # of detected car/ # of real parked car = 1.036
- Vary the depth threshold
Parking Availability Detection - Unslotted

- detected empty distance / actual empty distance = 0.963
- Vary the width threshold
Occupancy Map – Understand GPS Error

- GPS errors have strong spatiotemporal correlation
- Implies that we can use the reading from one object to correct the objects nearby
Occupancy Map – Environmental Fingerprinting

- Collect the real location of known static object
- GPS coordinates indicate system is near known object
- Parses rangefinder readings to get a series of dips
- Tries match the dips with consecutive known objects
- If object found, compute the offset as the GPS error
Occupancy Map – Full workflow

- Correct the location of parked vehicle using detected GPS error
- Assign the vehicle to the slots to minimize the total position differences

![Chart showing percentage errors with and without fingerprinting]
Mobility Study - Taxicab Routes

- SF GPS positions of 536 taxicabs for a month (every 60 seconds)
- Path were approximated by linear interpolation
- Determined the mean time between cabs visiting a particular road segment (cell).
Mobility Study - Cost Analysis

• ParkNet Cost:
  – Parknet: (~$400 per vehicle) x (# of vehicles needed to get desired rate of detection)

• Fixed Sensor:
  – ($250-800 per space) x (number of spaces)

• Example:
  – 6000 parking spots (SFpark)
  – ParkNet: 300 cabs, 80% coverage every 25 minutes, $0.12 million
  – Fixed Sensor: $1.5 million
Conclusions

• **Accuracy**
  – 95% accurate parking space counts
  – 90% accurate parking occupancy maps

• **Frequency and Coverage**
  – 536 vehicles equipped
  – Covers 85% every 25 minutes of a downtown area
  – Covers 80% every 10 minutes of a downtown area

• **Cost Benefits**
  – Estimated factor of 10-15 times cheaper than current systems
Limitations

• Multilane Roads
  – Moving cars could be determined by long dips
  – Rangefinder would need to be longer

• Speed Limitations
  – Sensors currently work best at speeds below 40mph

• Obtaining Parking Spot Maps
  – Difficult for large areas
  – Algorithms could determine location surroundings after data collection has been started

• Still Use Dedicated Sensor
Thank you for your attentions.
References

