How do I know, when this traffic signal will turn green?

Why do I want to know when the signal turns green?

Introduction

Traffic light countdown timer

Introduction

Traffic light countdown timer

Introduction

Traffic light countdown timer

- Expensive
- Impractical deployment
- Costly maintenance

Introduction

SignalGuru

Joint project of Princeton University and MIT

Demonstrates potential of smartphone cameras

Presented at MobiSys'11

Introduction

SignalGuru

Basic idea

- Take picture of intersection
- Filter out relevant traffic signal
- Predict the next green phase

Advantages

- No infrastructure
- Runs on mobile phones
- Detects and predicts traffic signals

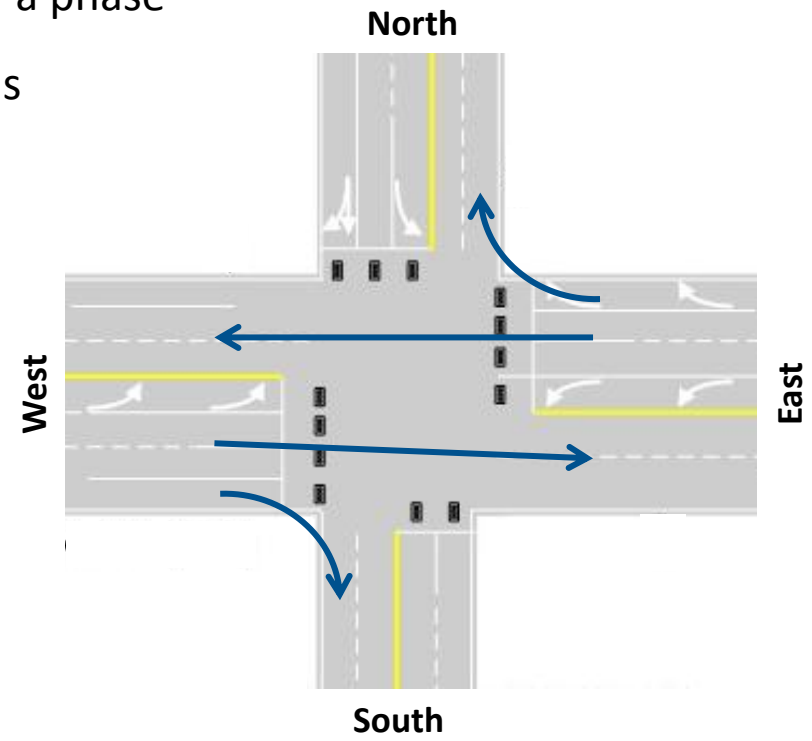
Outline

1. Traffic Light Background
2. SignalGuru
3. Applications
4. Related Work

Traffic Light Background

Terminology

- **Phase**: different, but non-conflicting movements
- **Cycle**: each phase had green once
- **Phase length**: green light duration for a phase
- **Cycle length**: sum of all phase lengths



Traffic Light Background

2 types of traffic lights

Pre-timed

- Settings (i.e. phase and cycle lengths) are fixed
- Same schedule repeats every cycle
- Typically 3 modes of operation

Adaptive

- Uses inductive loop detectors
- Adjusts settings based on lane saturation
- Changes settings every cycle
- Phases scheduled in deterministic, round-robin manner

Outline

1. Traffic Light Background
2. SignalGuru
   a) Modules
   b) Challenges
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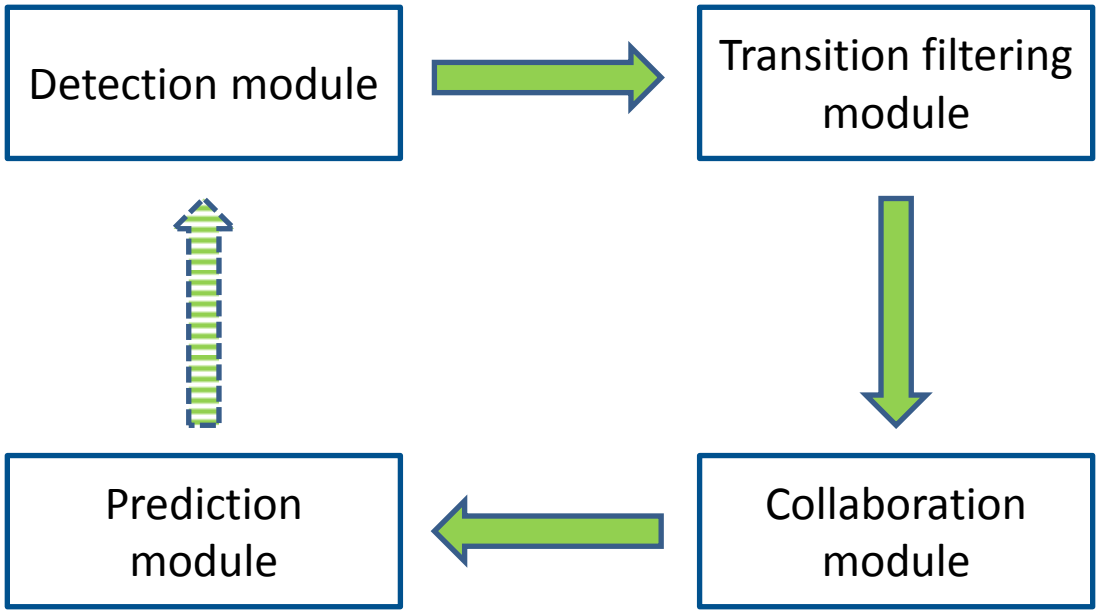
SignalGuru - Modules



SignalGuru - Detection

Setup

Windshield mounted iPhones

Phone cameras capture video frames

Detection activated based on GPS location

Processes a new frame every 2 seconds

SignalGuru - Detection

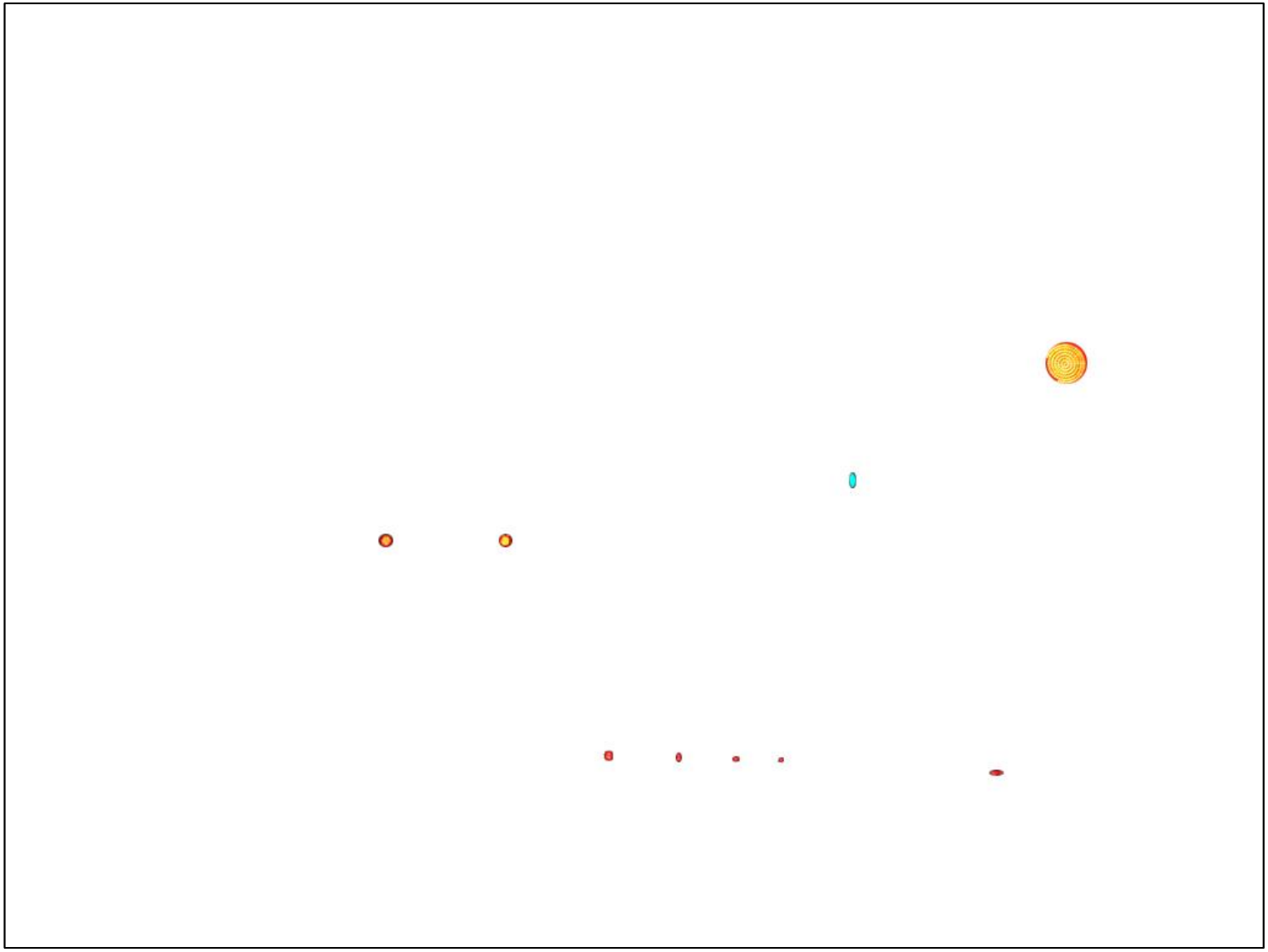
Characteristics of a traffic light

- Bright bulb colour
- Bulb shape (circle, arrow)
- Black traffic signal housing
- High above ground

SignalGuru - Detection

Colour filter

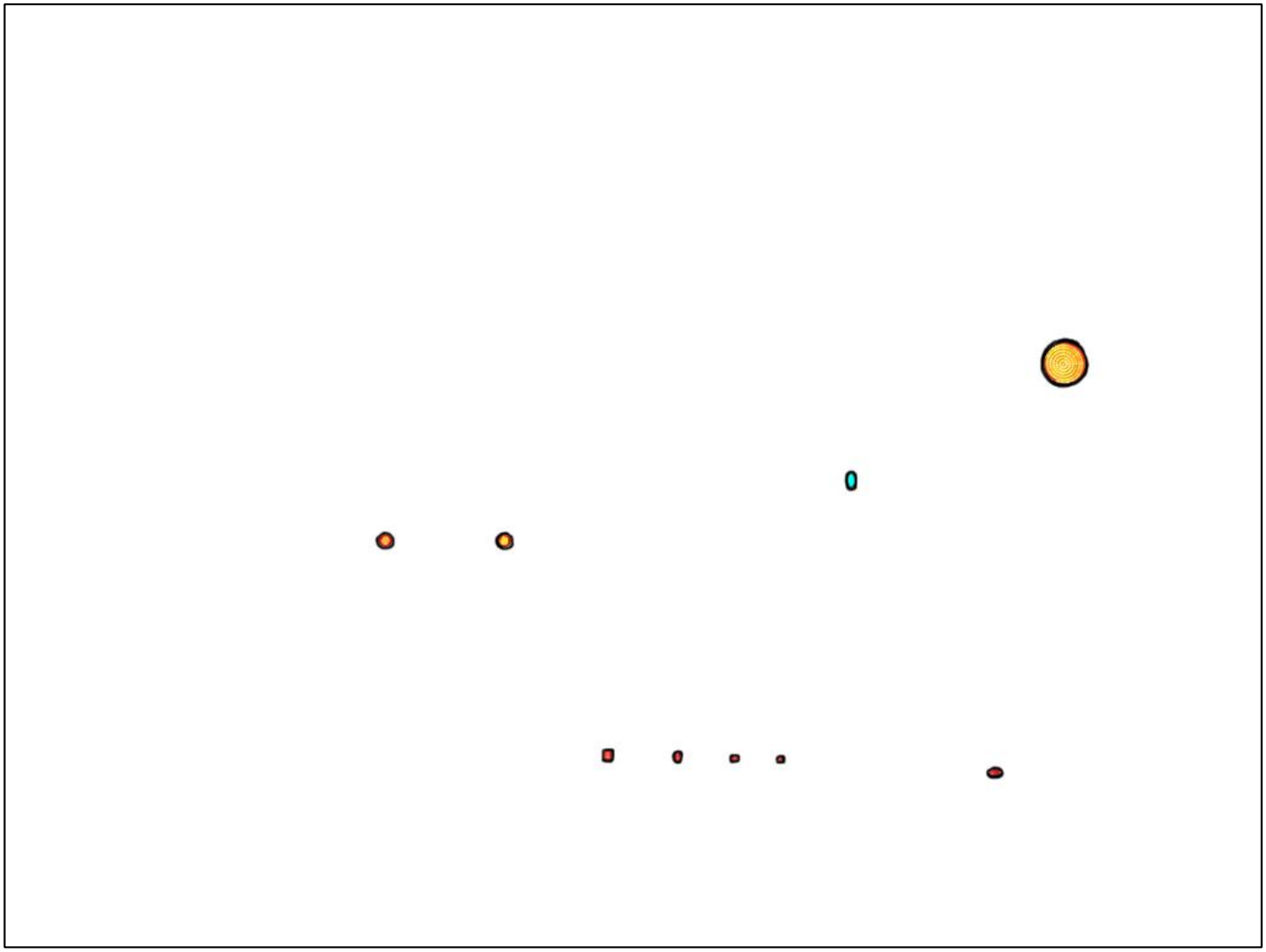
SignalGuru - Detection



SignalGuru - Detection

Colour filter → Laplace edge detection

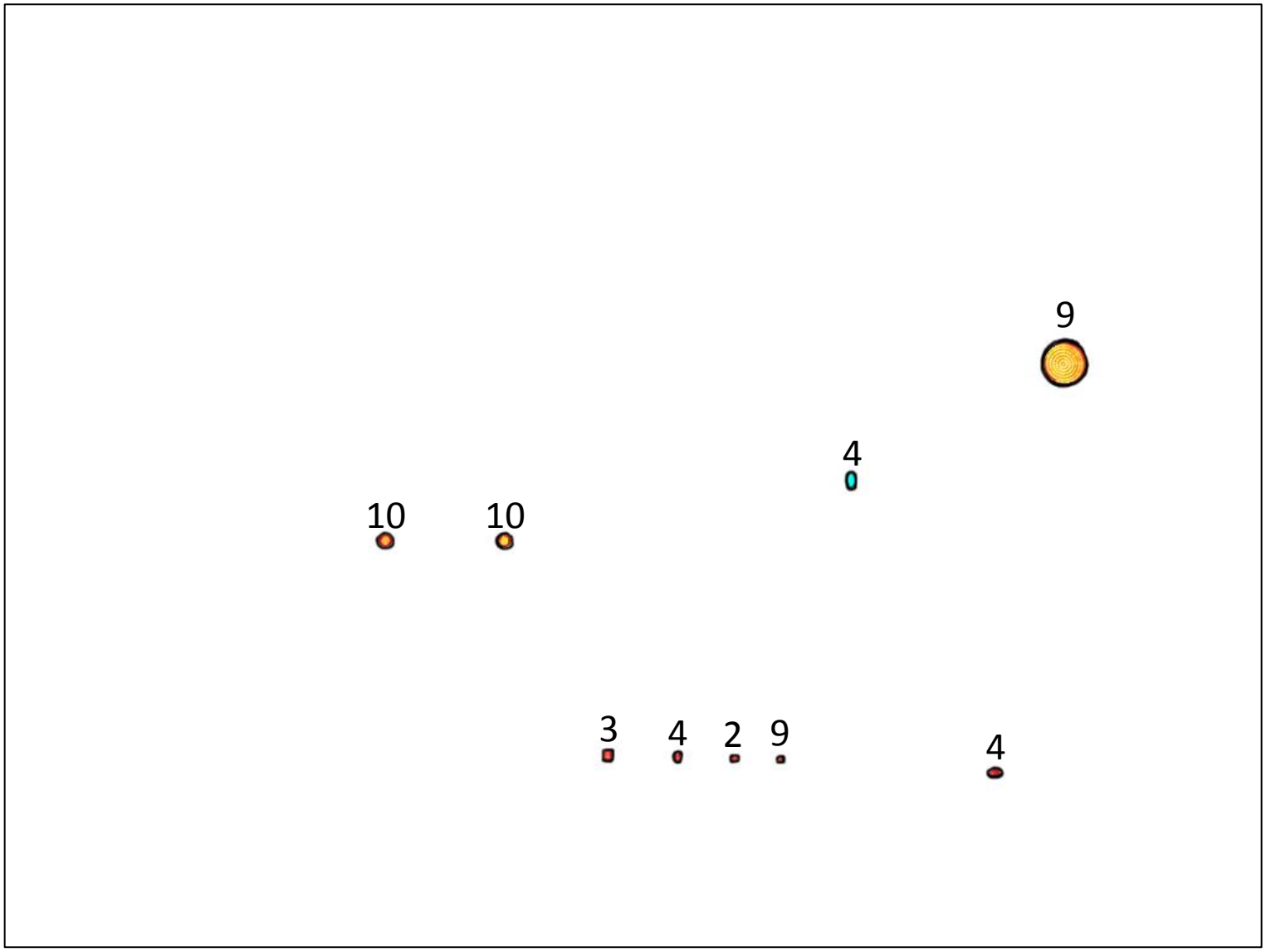
SignalGuru - Detection



SignalGuru - Detection

Colour filter → Laplace edge detection → Hough transform

SignalGuru - Detection



SignalGuru - Detection

Colour filter → Laplace edge detection → Hough transform → Calculate BCC and BBC ⇄ BCC ∗ BBC > threshold?

SignalGuru - Detection

BCC = **Bulb Colour Confidence**

Is the object in correct colour range?

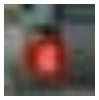

0.95

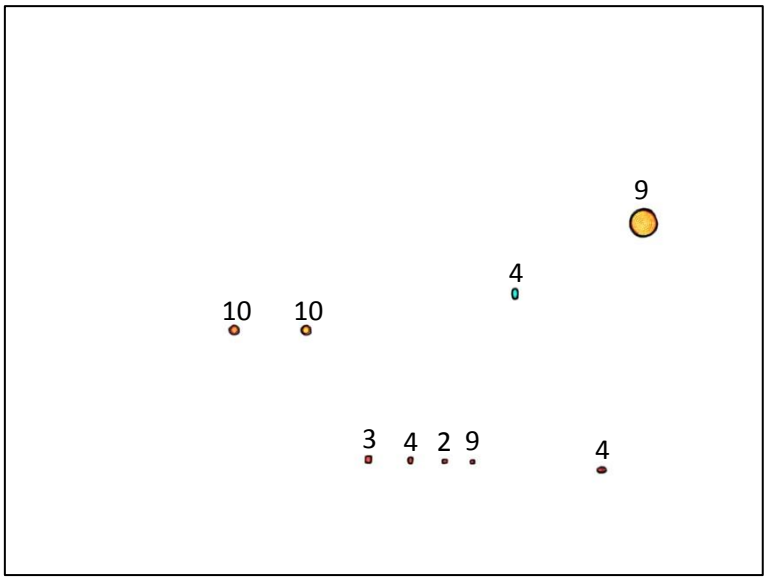

0.2

BBC = **Black Box Confidence**

Is the object surrounded by a traffic signal housing?


0.6


0.15



SignalGuru - Detection

Colour filter → Laplace edge detection → Hough transform → Calculate BCC and BBC

Calculate BCC and BBC ⇄ BCC * BBC > threshold?

BCC * BBC > threshold? → Report no traffic light found

BCC * BBC > threshold? → Report traffic light (colour, centre coordinates, radius)

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SignalGuru - Challenges

How to run everything with limited processing power?

Make use of high placement of traffic signals

Reduce detection window size

Benefits:

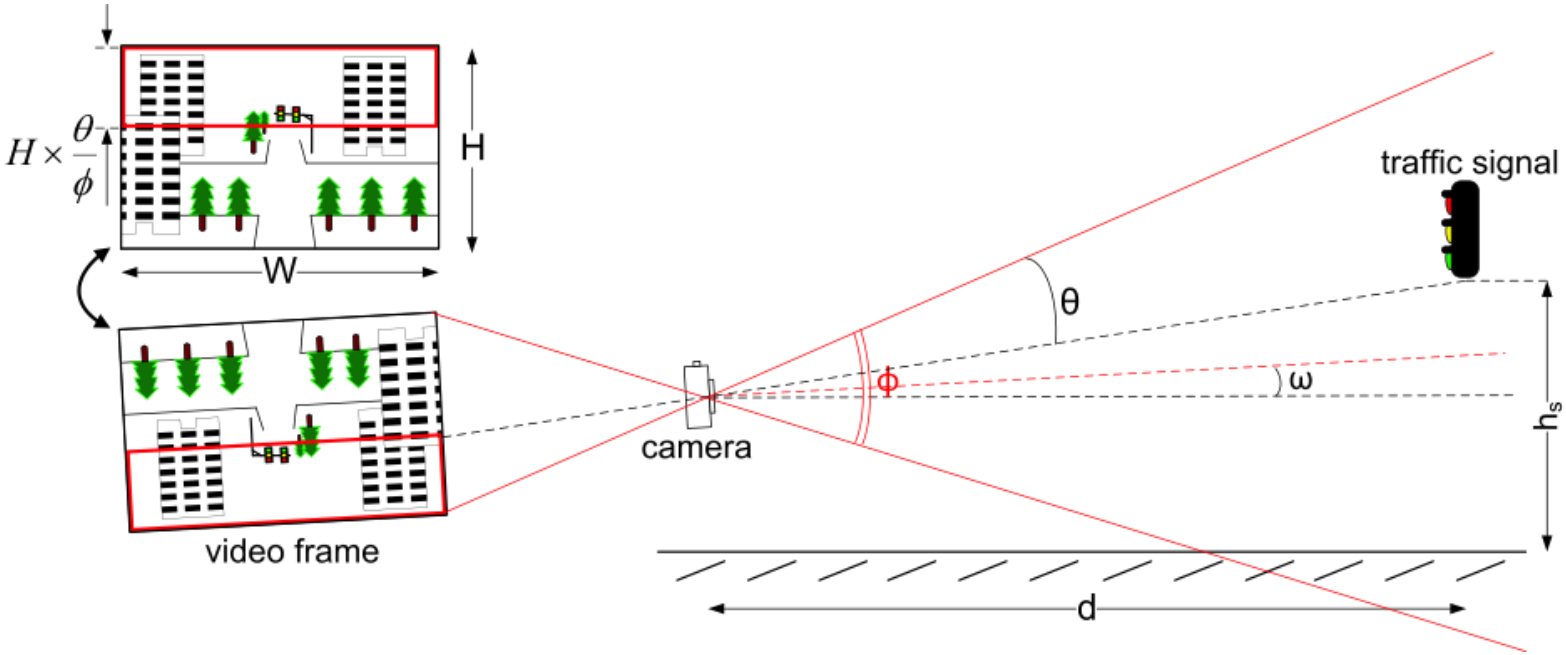
a) Processing time decreased by 41% (from 1.73s to 1.02s)

b) Almost halves misdetection rate (from 15.4% to 7.8%)

SignalGuru - Challenges

How to run everything with limited processing power?

Detection window

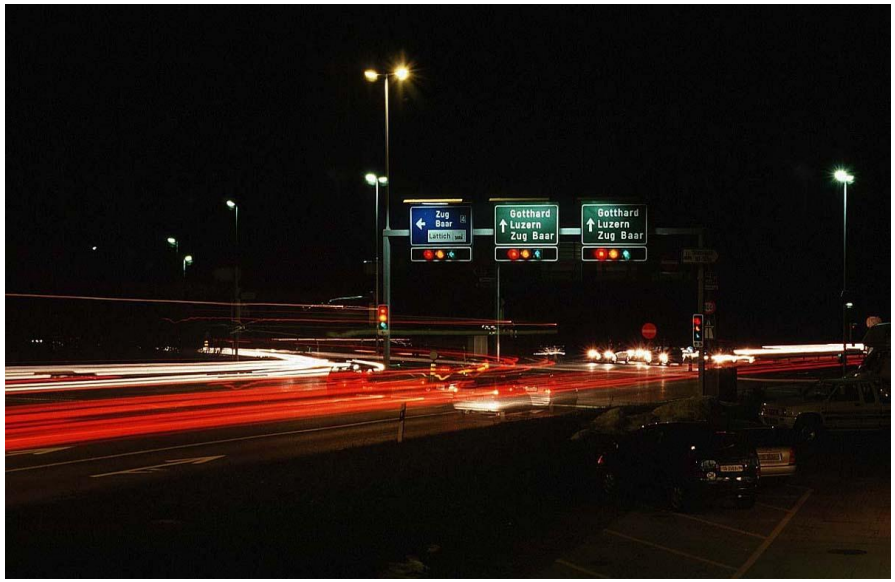


SignalGuru - Challenges

How to deal with variable ambient light conditions?

LED traffic signals have fixed intensity

Adjust and lock camera exposure time



SignalGuru - Detection in action

SignalGuru - Detection

Summary

Phone camera captures video frames

Algorithm filters out relevant traffic light

Reports location, radius and colour of a detected traffic light

Red
x:4.05, y: 3.22
r: 0.05

?

Signal will turn green in 24s

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SignalGuru - Transition Filtering

Detection module's output is fairly noisy

While waiting at traffic light: 65% false transition detection

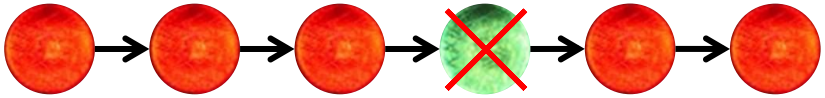
Need to filter out false positives

SignalGuru - Transition Filtering

Two-stage filter

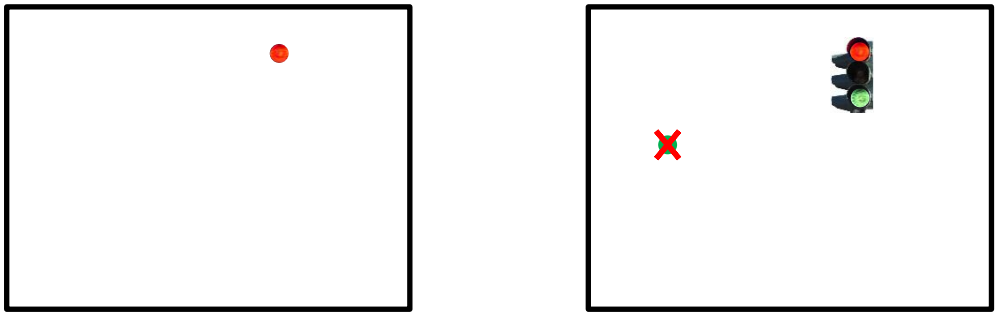
Low pass filter

88% of false positives in single frame



Colocation filter

Red and green bulb contained in the same black box



frame i

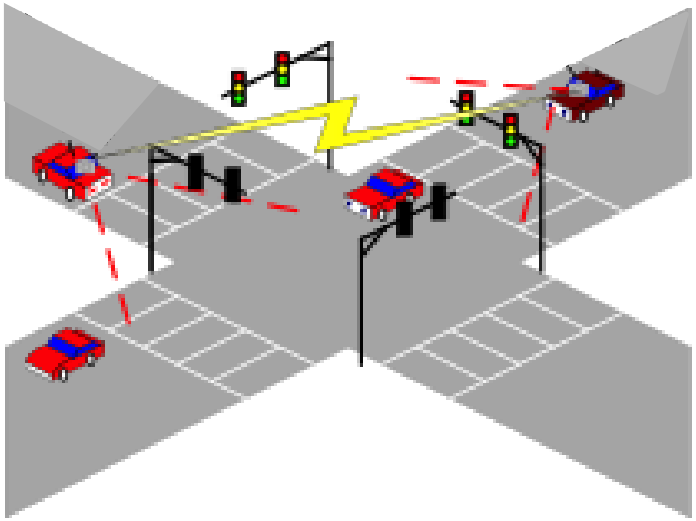
frame i + 1

SignalGuru - Collaboration

Exchange time stamped R -> G transitions

Use ad-hoc 802.11g network connection

The more transition data, the more accurate the prediction.



SignalGuru - Prediction

Pre-timed traffic signals

Main challenge:

Accurately synchronise SignalGuru's clock with phase transition

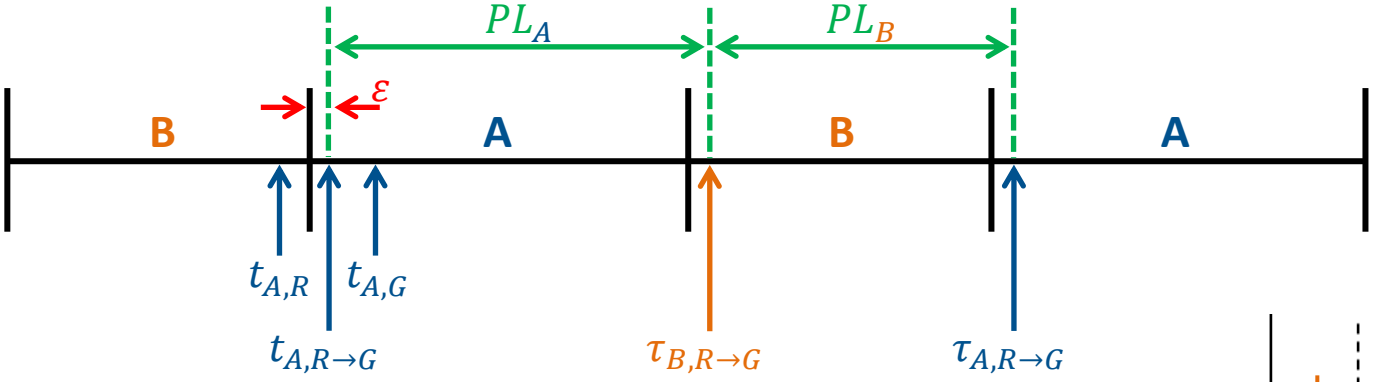
How it's done:

Achieved by capturing a colour transition

Rest of the data available from traffic authorities

SignalGuru - Prediction

Traffic signal timeline

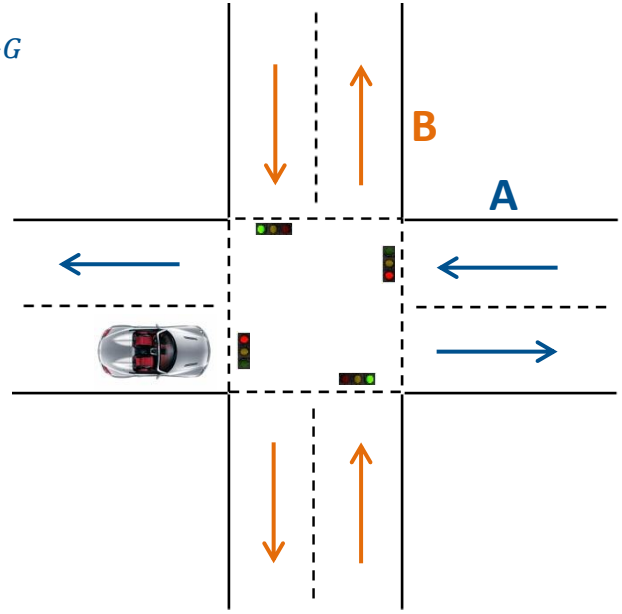


t = detected signals and transitions

PL = phase length

τ = predicted transitions

ε = error



SignalGuru - Prediction

Adaptive traffic signals

Main challenge:

Predict the phase length

How it's done:

Measure and collaboratively collect transition history

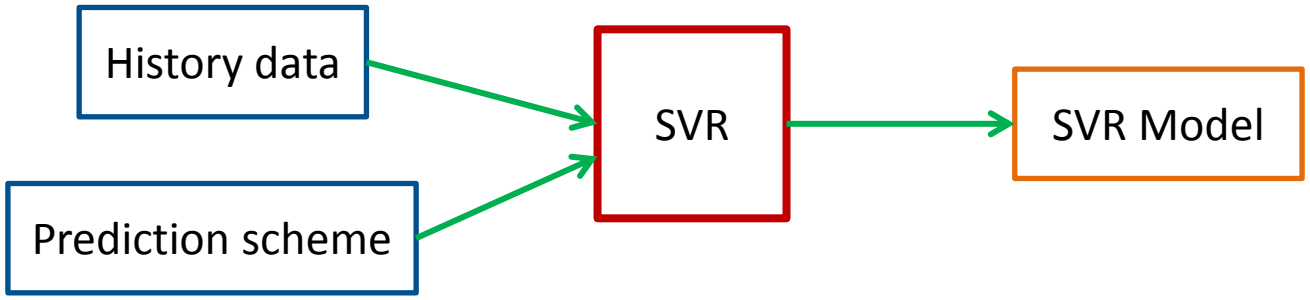
Feed data to Support Vector Regression prediction model

SignalGuru - Prediction

Support Vector Regression

2 phases:

1. Training: create a prediction model (offline)

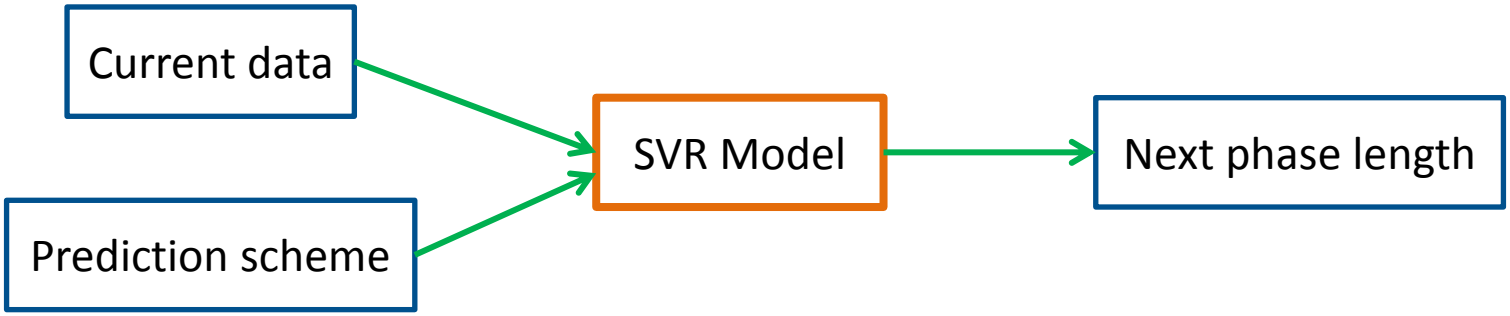


SignalGuru - Prediction

Support Vector Regression

2 phases:

1. Training: create a prediction model (offline)
2. Prediction: predict next phase length



SignalGuru - Prediction

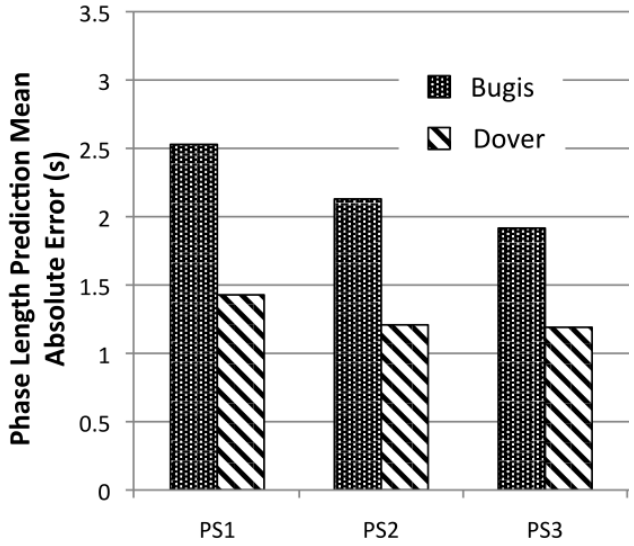
Support Vector Regression

Prediction schemes

PS1: Prediction based on history for the same phase

PS2: Also use lengths of preceding phases in same cycle

PS3: Use data of the last 5 cycles



Outline

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Applications - GLOSA

Green Light Optimal Speed Advisory

Advise drivers on optimal speed

Avoid stopping at red light

Benefits

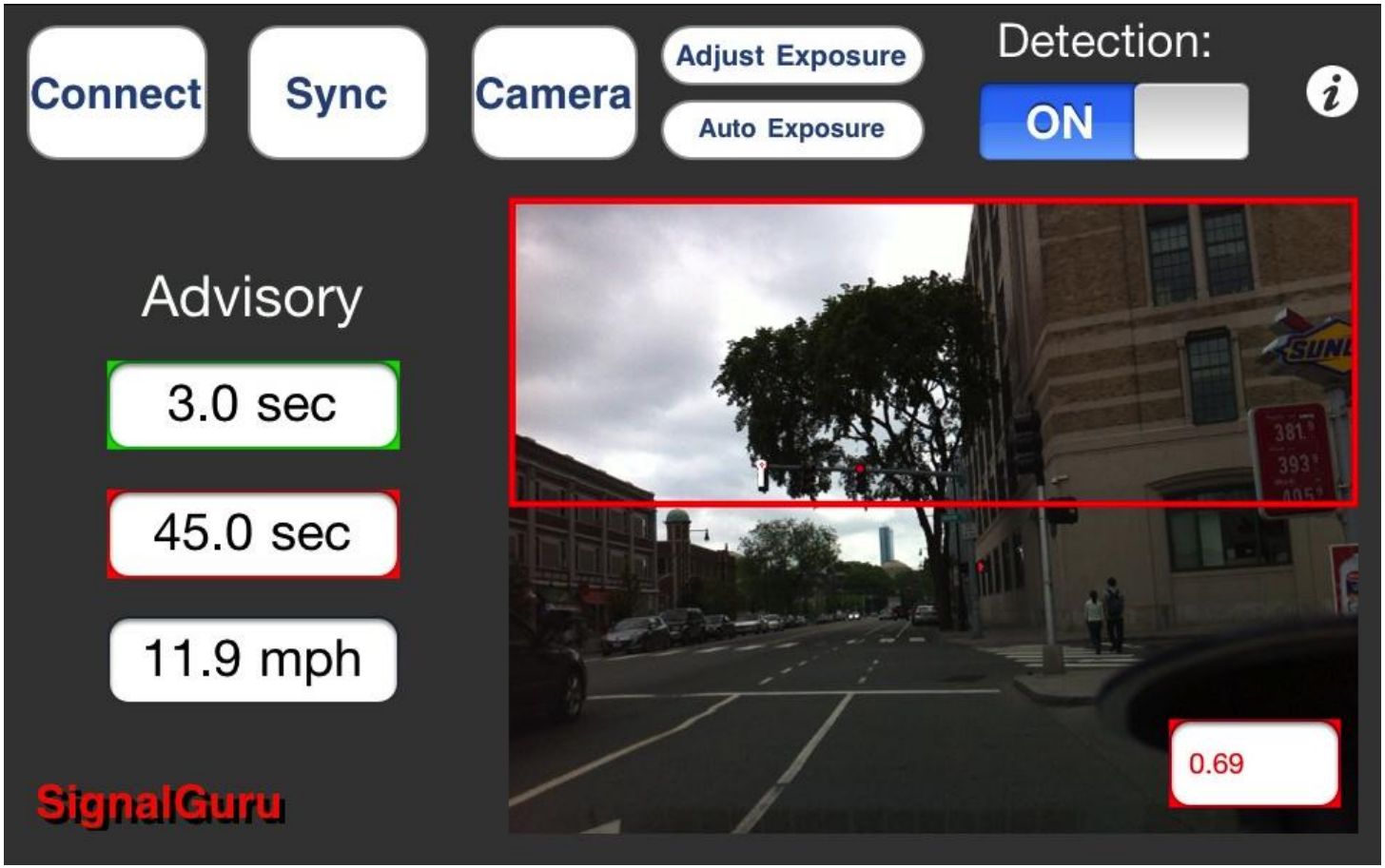
a) Decreases fuel consumption by 20%

b) Smoothens and increases traffic flow

c) Decreases environmental impact

Applications - GLOSA

SignalGuru's GLOSA screen



Applications - TSAN

Traffic Signal-Adaptive Navigation

Avoid long waits at red lights

Advise drivers on possible detours

Benefits

a) No stops at red lights

b) Reduces travel time

Outline

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Related Work

Hazardous Location Warning

Vehicle detects hazardous location, i.e. oil spill

Transmits data to oncoming vehicles

Makes use of

- Car sensors
- Ad-hoc network

Source: http://www.car-to-car.org/index.php?id=196

Related Work

ParkNet

Drive-by Sensing of Road-Side Parking Statistics

Project of Rutgers University, USA

Issue

Searching for parking spot creates congestion

Lead to a loss of $78 billion in 2007 in US

- 4.2 billion lost hours
- 11 billion litres of wasted fuel

Source: http://www.winlab.rutgers.edu/~gruteser/papers/mathur_parknet10.pdf

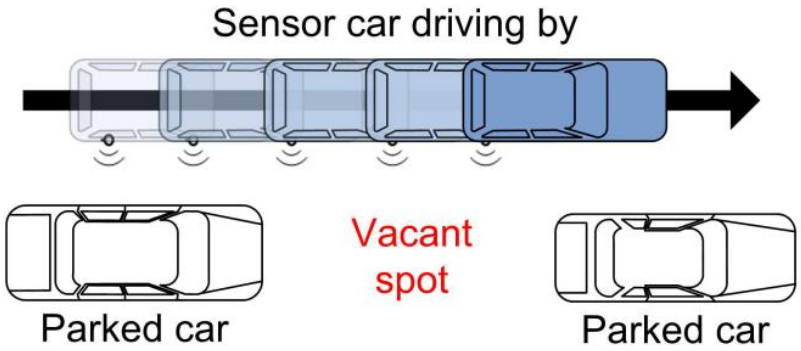
Related Work

ParkNet

Drive-by Sensing of Road-Side Parking Statistics

Mobile system with sensors on cars

Ultrasonic sensor and GPS receiver



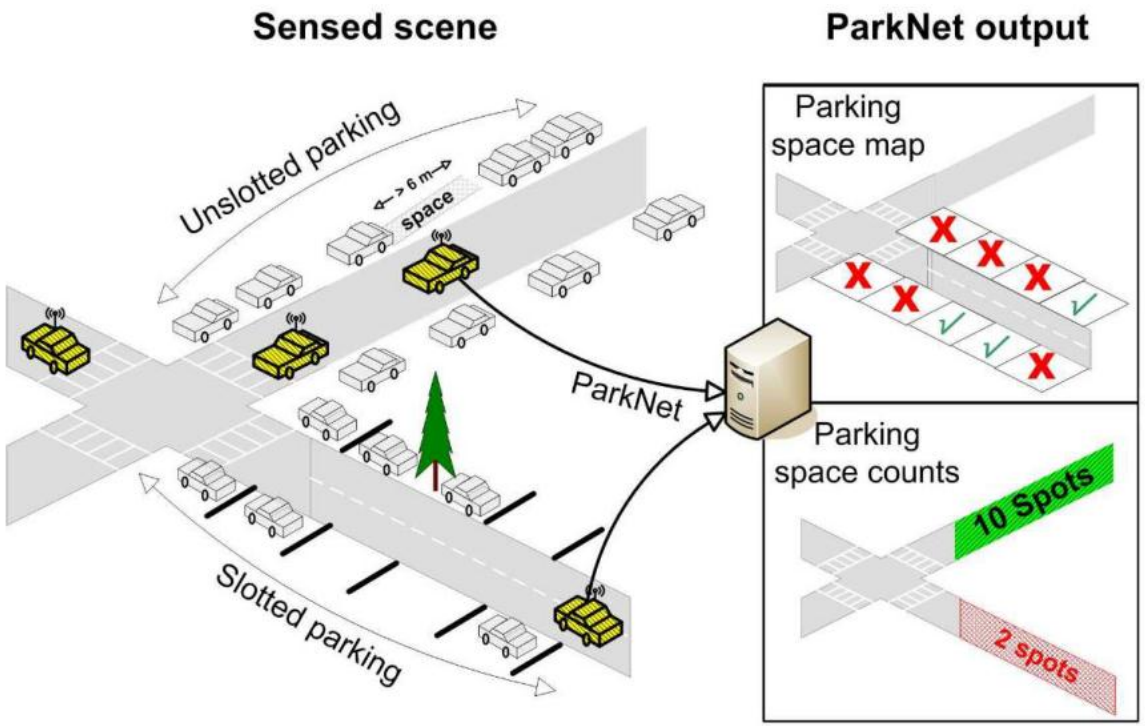
Source: http://www.winlab.rutgers.edu/~gruteser/papers/mathur_parknet10.pdf

Related Work

ParkNet

Data uploaded using Wi-Fi

Central server creates parking map



Related Work

ParkNet

Allows checking of near-real-time parking situation

Eliminates need to search for parking

Benefits

a) Saves time

b) Saves a lot of fuel

The End

Questions?

Thank you for your attention!