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

3. Applications

4. Related Work

How do I know, when the traffic signal will turn green?
SignalGuru - Modules

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

2. SignalGuru Modules
   - Detection
   - Transition Filtering
   - Collaboration
   - Prediction
SignalGuru - Detection

- Colour filter

2. SignalGuru Modules
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SignalGuru - Detection
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2. SignalGuru Modules
   - Detection
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   - Prediction

- Colour filter
- Laplace edge detection
SignalGuru - Detection

1. Colour filter
2. Laplace edge detection
3. Hough transform

2. SignalGuru Modules
   - Detection
   - Transition Filtering
   - Collaboration
   - Prediction
SignalGuru - Detection
SignalGuru - Detection

Colour filter → Laplace edge detection → Hough transform

BCC * BBC > threshold?

Calculate BCC and BBC
SignalGuru - Detection

BCC = Bulb Colour Confidence
Is the object in correct colour range?

BBC = Black Box Confidence
Is the object surrounded by a traffic signal housing?
SignalGuru - Detection

2. SignalGuru Modules
   - Detection
   - Transition Filtering
   - Collaboration
   - Prediction

- Colour filter
- Laplace edge detection
- Hough transform
- Report no traffic light found
- BCC * BBC > threshold?
- Calculate BCC and BBC
- Report traffic light (colour, centre coordinates, radius)
Outline

1. Traffic Light Background

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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

3. SignalGuru Challenges
   • Processing Power
   • Ambient Light Conditions
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: Traffic Signal Detection

Emmanouil Koukoumidis (MIT, Princeton)
Li-Shiuan Peh (MIT)
Margaret Martonosi (Princeton)
**SignalGuru - Detection**

**Summary**

Phone camera captures video frames

Algorithm filters out relevant traffic light

Reports location, radius and colour of a detected traffic light

![Image of a traffic light with coordinates and color]

Red

x: 4.05, y: 3.22

r: 0.05

Signal will turn **green** in 24s
Outline

1. Traffic Light Background

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   a) Modules
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How do I know, when the traffic signal will turn green?
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

2. SignalGuru Modules
   - Detection
   - Transition Filtering
   - Collaboration
   - Prediction
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
SignalGuru - Collaboration

Exchange time stamped R -> G transitions
Use ad-hoc 802.11g network connection

The more transition data, the more accurate the 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

\[ t = \text{detected signals and transitions} \]
\[ PL = \text{phase length} \]
\[ \tau = \text{predicted transitions} \]
\[ \epsilon = \text{error} \]
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
Support Vector Regression

2 phases:

1. **Training**: create a prediction model (offline)

Diagram:

- History data
- Prediction scheme
- SVR
- SVR Model
SignalGuru - Prediction

Support Vector Regression

2 phases:

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

Current data → SVR Model → Next phase length

- Detection
- Transition Filtering
- Collaboration
- Prediction

Prediction scheme
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

2. SignalGuru Modules
   • Detection
   • Transition Filtering
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   • Prediction

![Chart showing phase length prediction mean absolute error for PS1, PS2, and PS3 for Bugis and Dover]

28.03.2012
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Why do I want to know when a signal turns green?
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

3. SignalGuru Applications
   • GLOSA
   • TSAN
Applications - GLOSA

SignalGuru’s GLOSA screen

- Advisory:
  - 3.0 sec
  - 45.0 sec
  - 11.9 mph

SignalGuru Applications
- GLOSA
- TSAN
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

1. Traffic Light Background
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4. Related Work

- Location Warning
- ParkNet

## Hazardous Location Warning

Vehicle detects hazardous location, i.e. oil spill
Transmits data to oncoming vehicles

Makes use of

- Car sensors
- Ad-hoc network

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

Related Work

**ParkNet**

Drive-by Sensing of Road-Side Parking Statistics

Mobile system with sensors on cars

Ultrasonic sensor and GPS receiver

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!