SignalGuru:  
Leveraging Mobile Phones for Collaborative 
Traffic Signal Schedule Advisory

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MobiSys, June 29th 2011
Cars are big polluters & energy hogs

- Produce 32% of total CO₂.
- Consume 28% of USA’s total energy.
- 10 times the energy for computing infrastructure.

* Source: US Environmental Protection Agency (http://www.epa.gov/)*
Traffic Signals - GLOSA

• Traffic signals:
  (+) Provide safety.
  (-) Enforce a stop-and-go movement pattern.
  • Increases fuel consumption by 17%*.
  • Increases CO₂ emissions by 15%*.

• Solution: Green Light Optimal Speed Advisory (GLOSA).

* Source: Audi Travolution Project

Need to know the schedule of traffic signals.
## Signal Schedule Advisory Systems

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Thailand
Design: Damjan Stankovich
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SignalGuru Approach
Challenges

• Commodity cameras. Low video resolution:
  – iPhone 4: 1280 × 720 pixels.
  – iPhone 3GS: 640 × 480 pixels

• Limited processing power.
  – But need high video processing frequency.

• Uncontrolled environment.

• Traffic-adaptive traffic signals.

• Non-challenge: Energy.
Detection Module

- Detects signal current status (Red/Yellow/Green) from video.
- New frame every 2sec.
- Main features:
  - Bright color.
  - Shape (e.g., round, arrow).
  - Within black housing.
  - Location in frame (detection window).
IMU-based Detection Window

- Roll angle $\omega$ is calculated by gyro and accelerometer data.
- Process only area within detection window.
- Cuts off half of the image:
  - Processing time reduced by 41%.
  - Misdetection rate reduced by 49%.
SignalGuru: Traffic Signal Detection
Transition Filtering Module

- Filters out false positives.
- Low Pass Filter:
  \[ \ldots \rightarrow R \rightarrow R \rightarrow R \rightarrow G \rightarrow R \rightarrow R \rightarrow \ldots \]
- Colocation filter.
  - Red and Green bulbs should be collocated.

- Filters compensates for lightweight but noisy detection module.
Collaboration Module

• No cloud server.
• Real-time adhoc exchange of timestamped R→G transitions (last 5 cycles) database.
• Collaboration:
  – Improves mutual information.
  – Enables advance advisory.
Prediction Module

• Add to timestamp of phase A’s detected R→G transition \( (t_{A, R\rightarrow G}) \) the predicted Phase Length of A \( (PL_A) \) to predict R→G transition for B \( (t_{B, R\rightarrow G}) \).

\[
\begin{align*}
B & \quad A & \quad B & \quad A \\
\uparrow & \quad PL_A & \quad \uparrow \\
t_{A, R\rightarrow G} & \quad t_{B, R\rightarrow G} 
\end{align*}
\]

• Phase Length prediction:
  • Pre-timed signals: Look-up in database.
  • Traffic-adaptive traffic signals: Predict based on history of settings using machine learning (SVR).
SignalGuru/GLOSA iPhone Application

Residual amount of time in sec until the traffic signal turns green.

Residual amount of time in sec until the traffic signal turns red again.

Recommended GLOSA speed.
SignalGuru Evaluation
SignalGuru Evaluation

Cambridge (MA, USA)

Singapore
Cambridge (MA, USA)

- Pre-timed traffic signals.
- Experiment:
  - 5 cars over 3 hours.
  - 3 signals, >200 transitions.

\[ \text{Error}_{\text{Average}} = 0.66 \text{sec (2%).} \]
Singapore: Prediction Accuracy Evaluation

- Traffic-adaptive traffic signals.
- Experiment in downtown:
  - 8 cars over 30 min.
  - 2 signals, 26 transitions.

SignalGuru accurately predicts both pre-timed and traffic adaptive traffic signals.

Error\text{Average} = 2.45\text{sec} (3.8\%).
- Error\text{Transition Detection} = 0.60\text{sec} (0.9\%).
- Error\text{Phase Length Prediction} = 1.85\text{sec} (2.9\%).
Evaluation: GLOSSA Fuel Savings

- Trip: $P_1$ to $P_2$ through 3 signalized intersections.
- 20 trips to measure fuel consumption.
2.4L Chrysler PT Cruiser ’01

SignalGuru/GLOSA-enabled iPhone
Scan Tool
OBD-LINK device

OBDWiz software (IMAP)
Evaluation: GLOSA Fuel Savings

- Without GLOSA driver made on average 1.7/3 stops.

Average fuel consumption reduced by 20.3%.
Conclusions

• With selective accelerometer- and gyro-based image detection and filtering near real-time and accurate image processing can be supported.
• SignalGuru predicts accurately both pre-timed and traffic-adaptive traffic signals.
• SignalGuru-based GLOSA helps save 20% on gas.
Thank you!
Questions?

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http://www.princeton.edu/~ekoukoum/

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