Challenges In Communication Assisted Road Transportation Systems for Developing Regions

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Congestion scenario in Indian roads

Divider??

Too many cars, too little roads
Congestion scenario in Indian roads

Direction of Traffic ??

Overtaking on the wrong side
## On-road sensing techniques

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Installation &amp; maintanence cost</th>
<th>Lane system (orderliness) assumption</th>
<th>Freeway traffic assumption</th>
<th>Low variation in vehicle speed assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual loop detector based congestion detection [1]</td>
<td>High</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Magnetic-sensor based congestion detection [2]</td>
<td>Moderate</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Image-sensor based congestion detection [3, 4]</td>
<td>High</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
(In)Applicability of existing ITS techniques in Indian Roads

Probe-vehicle based approaches

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Installation &amp; maintainence cost</th>
<th>Lane system (orderliness) assumption</th>
<th>Freeway traffic assumption</th>
<th>Low variation in vehicle speed assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time prediction for freeways [5, 6]</td>
<td>Low</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>KFT based bus arrival time prediction [7]</td>
<td>Low</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cell phone based travel time prediction [8, 9]</td>
<td>Low</td>
<td>No</td>
<td>Partial</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Conclusion

Some lessons from prior ITS literature, but mostly work from scratch required.
ITS efforts in India

Recent approaches

- GPS-based bus arrival time prediction in Chennai: [10]
- Nericell [11]: detection of road congestion, road surface conditions
  - Sensors: accelerometer, microphone, GPS receiver on high end mobile phones
  - Test pilots in Bangalore
- These provide valuable insights; but much remains to be done

Our work: Communication Assisted Road Transportation Systems (CARTS)

- **Goal:** device architecture, sensing techniques, algorithms for effective traffic congestion detection/alleviation on Indian roads.
- **Principle:** India is unique, treat it so
- **Current focus:** can honks be used intelligently?
Can Honks be Used Intelligently?

Intuition

- Honks omnipresent, tied to driving protocol
- Easily distinguishable from other sounds
- Sensor required: road-side microphone; can be inexpensive

Using Honks

- Amplitude variation to detect speed: not yet explored
- Doppler shift: current focus
央

catch honk as vehicle crosses sensor
That is, we can only use such honk samples
This can be checked by looking for amplitude change
Assuming speed $V_{\text{vehicle}}$ is constant,

$$V_{\text{vehicle}} = \frac{f_1 - f_2}{f_1 + f_2} \cdot V_{\text{sound}}$$  \(1\)

- $f_1$, $f_2$: dominant frequency components before and after vehicle crosses sensor
- **Note-1**: no need to know the honk frequency
- **Note-2**: cannot know vehicle direction
Experiments Using One Microphone

Setup

- IBM Thinkpad R6li placed along the roadside
- Audio signals recorded at the sampling rate of 44 KHz
- Bike driven on the road, honking past sensor
- **Note**: Ground truth from speedometer (approximate)

Results

<table>
<thead>
<tr>
<th>Actual speed (Kmph)</th>
<th>$f_1$ (Hz)</th>
<th>$f_2$ (Hz)</th>
<th>Estimated speed (Kmph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2908</td>
<td>2834</td>
<td>15.7</td>
</tr>
<tr>
<td>30</td>
<td>2929</td>
<td>2831</td>
<td>20.8</td>
</tr>
<tr>
<td>40</td>
<td>2939</td>
<td>2801</td>
<td>29.4</td>
</tr>
</tbody>
</table>

Table: Estimated speeds using only one microphone
Speed Estimation Using Two Microphones

- **Single microphone: disadvantages**
  - Only long honks can be used: relatively rare
  - More problematic at lower speeds (at high congestion)
  - Vehicle direction not known

- **With two microphones separated by known distance:**
  - Any honk in-between two sensors gives speed estimate, with direction

![Diagram of Central Server with f1, f2, b, c, h, and d](image)

Central Server

- **Central Server**
- **f1, f2, b, c**
- **h**
- **d**
- Direction of vehicle motion

- **Equations:**
  - Central Server: $h$
  - Distances: $20m$, $66m$, $d$

- **Central Server Variables:**
  - $h$
  - $20m$
  - $66m$
  - $d$

- **Direction of Vehicle Motion:**
  - Arrows indicate direction of vehicle motion

- **Mathematical Formulas:**
  - Speed estimation with two microphones
  - Direction calculation

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Issue-1: Precise Honk Detection

- Honk detection condition, within test window:
  \[
  \text{Amp. in } 2 - 4\text{KHz} > T \times \text{Avg. amp. in all freq.}
  \]  
  \(2\)

- Need to detect honk window **precisely**

- **Window size:** 8ms; At 16KHz sampling, 128 samples
  - Small window size ⇒ honk detection more precise
  - 128 point FFT is very coarse granularity
  - But is good enough for honk detection

- Consider only honks > 40ms length (5 consecutive 8ms windows)

- **After detection:** 2048 point FFT for accurate analysis
Issue-2: Honk Matching Across the Two Sensors

- Sub-issue: need synchronization; can be achieved by WiFi/ZigBee radio
- From vehicle location, attenuation levels, propagation delays different to \( S_1 \) and \( S_2 \)
- Honk durations are different too (Doppler)
- Goal: want to detect windows in the middle part, say \( D/2 \), of \( S_1 \) and \( S_2 \)

\[
|t_1 - t_2| < \frac{0.5 \times D}{V_{\text{sound}}} + \text{margin} \quad (3)
\]

- For \( D = 34m \), \( |t_1 - t_2| < 80ms \) worked well
- **What did not work:** comparing honk durations
Experiments Using Two Microphones

Setup

Two microphones were placed along the same side of the road with distance between them 66m. Distance of bike’s line of motion from the microphones was varied as 2m, 6m and 10m. Bike was made to honk for small durations 7 times, while its speed was varied from 20-40 Kmph, in steps of 10Kmph.

Results

<table>
<thead>
<tr>
<th>Distance, d (m)</th>
<th>Actual speed(Kmph)</th>
<th>Honks matched</th>
<th>Estimated speed in Kmph(std. deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20</td>
<td>1</td>
<td>15.2 (0.0)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>3</td>
<td>15.2 (3.0)</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>2</td>
<td>15.2 (0.0)</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>2</td>
<td>19.0 (1.3)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>4</td>
<td>20.3 (4.4)</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>3</td>
<td>21.9 (1.2)</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>3</td>
<td>28.7 (4.8)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>4</td>
<td>31.5 (3.7)</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>3</td>
<td>33.8 (4.4)</td>
</tr>
</tbody>
</table>
Conclusion

Contribution

- Early exploration of honk-based speed detection
- We are able to estimate speeds, with $\approx 10\text{Kmph}$ inaccuracy
- Mostly able to distinguish speed ranges

Future work

- Improvement of algorithms to detect, match honks
- Experiments on real roads, ground truth verification
- Algorithms for traffic condition classification into slow, medium or fast from individual vehicle speeds

Questions?
Vehicle reidentification and travel time measurement on congested freeways. 

Traffic measurement and vehicle classification with a single magnetic sensor. 

Detection of traffic congestion in optical remote sensing imagery. 

[4] Li Li, Long Chen, Xiaofei Huang, and Jian Huang. 
A traffic congestion estimation approach from video using time-spatial imagery. 
In *ICINIS '08, First International Conference on Intelligent Networks and Intelligent Systems.*

Vehicles as probes.
Application of probe vehicle data for real-time traffic state estimation and short-term travel time prediction on a freeway. 

Transit vehicle arrival prediction: An algorithm and a large scale implementation. 

[8] Brian Smith, Han Zhang, Mike Fontaine, and Matt Green. 
Cellphone probes as an atms tool. 
Smart travel lab report no. stl-2003-01, Center for Transportation Studies, University of Virginia, June 2003.

Travel time estimation on the san francisco bay area network using cellular phones as probes. 