Challenges In Communication Assisted Road Transportation Systems for Developing Regions

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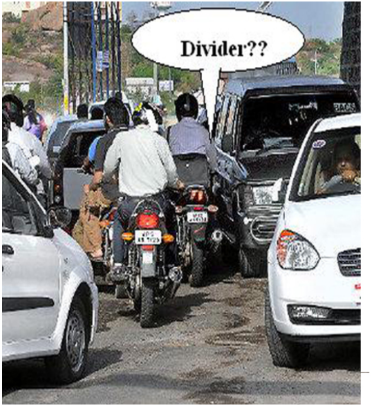
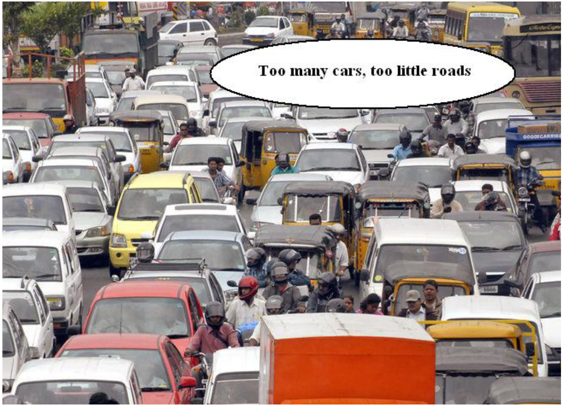
Congestion scenario in Indian roads





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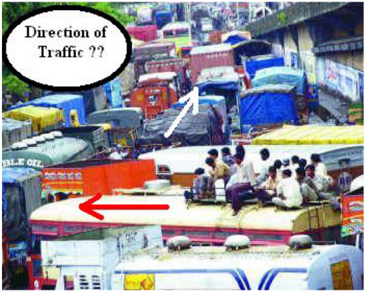


(In)Applicability of existing ITS techniques in Indian Roads

On-road sensing techniques

Techniques	Installation & maintanence cost	Lane system (orderliness) assumption	Freeway traffic assumption	Low variation in vehicle speed assumption
Dual loop detector based congestion detection [1]	High	Yes	No	No
Magnetic-sensor based congestion detection [2]	Moderate	Yes	No	Yes
Image-sensor based congestion detection [3, 4]	High	Yes	No	No

(In)Applicability of existing ITS techniques in Indian Roads

Probe-vehicle based approaches

Techniques	Installation & maintanence cost	Lane system (orderliness) assumption	Freeway traffic assumption	Low variation in vehicle speed assumption
Travel time prediction for freeways [5, 6]	Low	No	Yes	Yes
KFT based bus arrival time prediction [7]	Low	No	No	Yes
Cell phone based travel time prediction [8, 9]	Low	No	Partial	Yes

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?

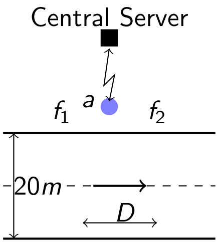
Intuition

- 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

Speed Estimation With One Microphone



- **Idea:** 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 $V_{vehicle}$ is constant,

$$V_{vehicle} = \frac{f_1 - f_2}{f_1 + f_2} \cdot V_{sound} \tag{1}$$

- 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)

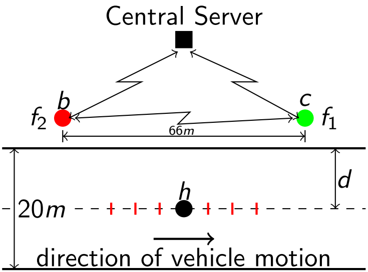
Results

Actual speed (Kmph)	$f1$ **(Hz)**	$f2$ **(Hz)**	**Estimated speed (Kmph)**
20	2908	2834	15.7
30	2929	2831	20.8
40	2939	2801	29.4

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



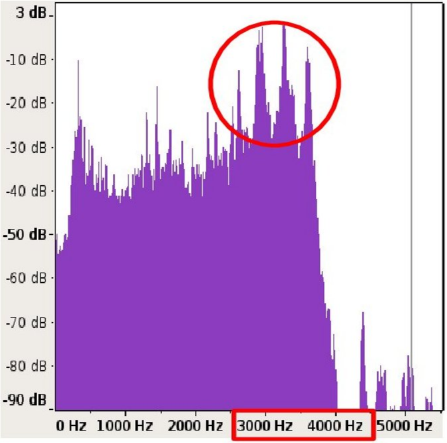
Issue-1: Precise Honk Detection

- Honk detection condition, within test window:

$$Amp.\ in\ 2-4KHz > T \times Avg.\ amp.\ in\ all\ freq. \quad (2)$$

- 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

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

- 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

Distance, d (m)	Actual speed(Kmph)	Honks matched	Estimated speed in Kmph(std. deviation)
2	20	1	15.2 (0.0)
6		3	15.2 (3.0)
10		2	15.2 (0.0)
2	30	2	19.0 (1.3)
6		4	20.3 (4.4)
10		3	21.9 (1.2)
2	40	3	28.7 (4.8)
6		4	31.5 (3.7)
10		3	33.8 (4.4)

Conclusion

Contribution

- Early exploration of honk-based speed detection
- We are able to estimate speeds, with $\simeq 10 Kmph$ 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?

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