HORN-OK-PLEASE

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1 Background

An Intelligent Transport System (ITS) For Developing Regions

A chaotic intersection in the Indian city Hyderabad

Motivation for ITS

- Too many vehicles, too little road
- Infrastructure growth slow due to lack of funds, space and bureaucratic issues
- Alleviating problem using technology

State of the art in ITS

Fixed sensor based
Sensors fixed by road side or under road surface

Eg. - Dual loop detector, Image sensor, Magenetic sensor

Mobile sensor based
Sensors placed in probe vehicles

Eg. - GPS receiver, smartphone's accelerometer & microphone

Challenges in developing regions

- ✘ High installation and maintainance *costs*
- ✘ Assumption of *lane based system*
- ✘ Assumption of *low variability in vehicle speed*
- ✘ *Low proliferation* of GPS and smartphones
- ✘ *Lack of incentive* in participatory sensing
- ✘ *Power drainage* issue of phones
- ✘ *Privacy* issues

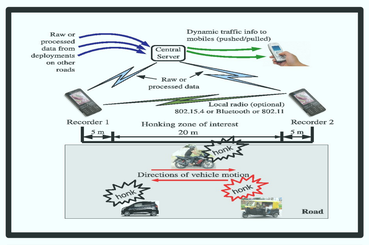
Goal : To design a *low cost* ITS that can *differentiate free flowing traffic state from congestion* even in *chaotic conditions*

System Architecture : Doppler Shift of Honks

$$f_1 = \frac{v}{(v+v_s)} \times f_0$$

$$f_2 = \frac{v}{(v-v_s)} \times f_0$$

$$v_s = \frac{(f1-f2)}{(f1+f2)} \times v$$



Questions

- How to *estimate* vehicle speeds from honks ?
- Are there *enough* honks on road ?
- Will estimated speeds represent the *traffic state*?
- Can *congested vs freeflow* traffic states distinguished?
- What other non-speed based *acoustic* metrics can be used to identify traffic states ?

Algorithm Design : Challenges

- How to *detect honks* in presence of significan road noise ?
- How to *match honks* across two acoustic sensors ?
- How to *extract f1 and f2* from a pair of matched honks ?

Extensive Road Experiments

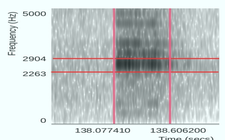
Hardwares and Softwares used

Extensive semicontrolled experiments done inside IIT Bombay campus to design the speed estimation algorithm

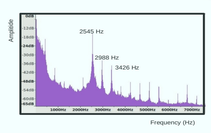
Recording : Hardware & Parameters

- Voice recorder of Nokia N79
- 16 KHz sampling frequency
- Mono channel
- 16 bit encoding
- Wav format

Audio Analysis Softwares



Praat

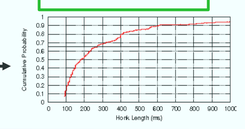


Audacity

Honk Empirical Data

- Honk frequency range – 2-4 Khz
- Average number of honks per clip - 30
- Honk length - CDF →

3 hours of data = 18 clips of 10 mins each



2 Approach

3 Algorithm

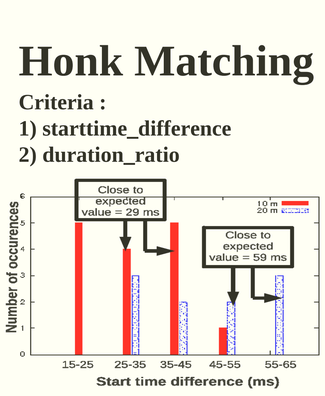
Honk Detection

1) PeakVsAvgAllFreq
2) PeakVsAvgHonkFreq
3) PeakAbsAmp

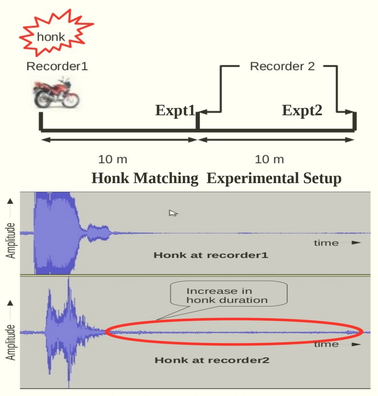
	PeakVsAvgAllFreq		PeakVsAvgHonkFreq		PeakAbsAmp	
Stage	fp (%)	fn (%)	fp (%)	fn (%)	fp (%)	fn (%)
Default	22.3	0.2	2.3	61	18.9	0.3
length bounding	5.6	0.7	0.03	93.8	10	1.04
honk merging	5.7	0.4	0.03	93.7	10.3	1.01

Honk Matching

Criteria :
1) starttime_difference
2) duration_ratio

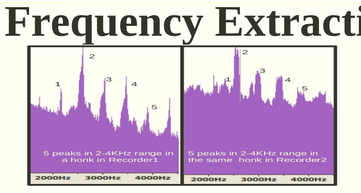


Start time difference hould be 28-30 ms at 10 m and 57-59 ms at 20 m with sound speed 340-350 m/sec

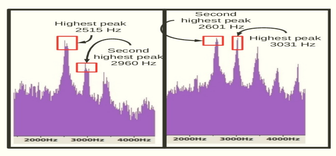


Duration ratio should be 1 for stationary bike, which is not so. So only starttime_difference is used for matching.

Frequency Extraction

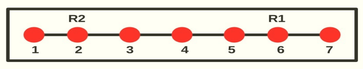


Local maximas same after Doppler shift

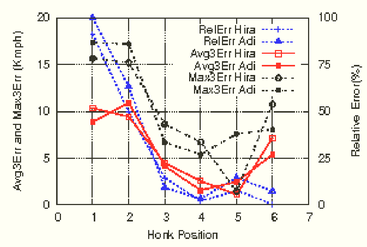


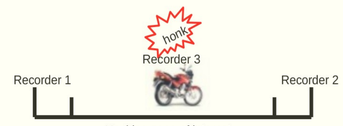
Exchange of top two local maximas

Evaluation

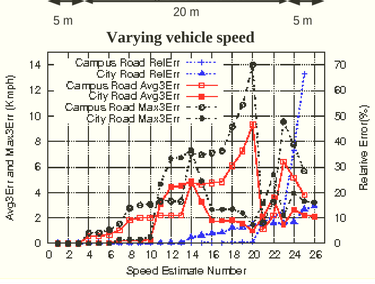


Varying Honk Positions





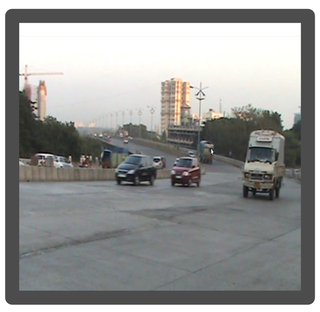
Varying vehicle speed



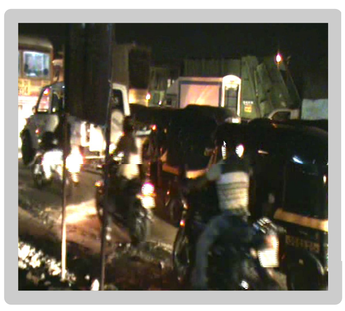
4 Evaluation

Road Experiments

- 18 hours of road data collection
- 2 different roads
- Different times of the day
- Different weather conditions



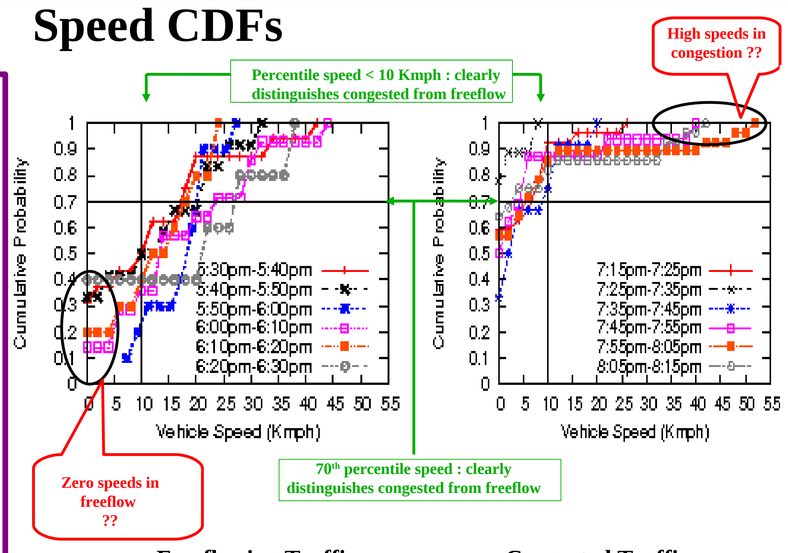
4.30 pm : Freeflowing



7.30 pm : Highly Congested

Adi Shankaracharya Marg (outside IITB, notorious for congestion)

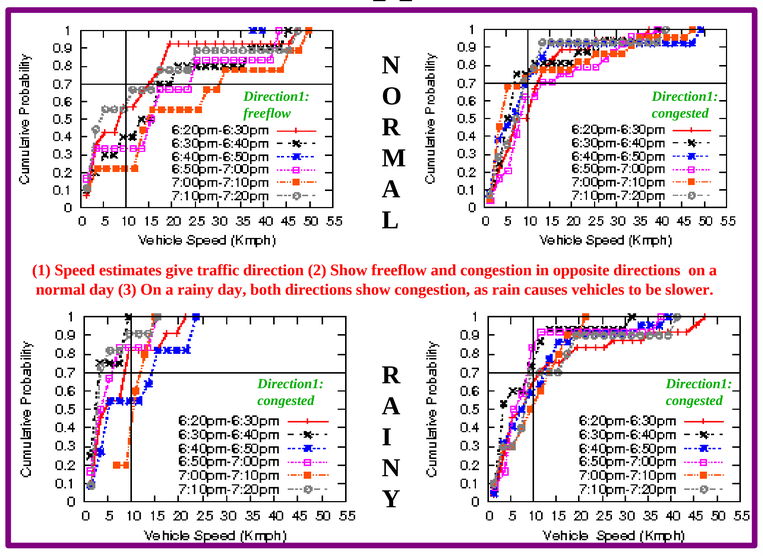
Speed CDFs



Freeflowing Traffic

Congested Traffic

Same Road : Opposite Directions



(1) Speed estimates give traffic direction (2) Show freeflow and congestion in opposite directions on a normal day (3) On a rainy day, both directions show congestion, as rain causes vehicles to be slower.

Congested *vs* Freeflowing : Metrics

70th Percentile Speed(Kmph)
direction sensitive
Percentile of Speed < 10 Kmph

Metric	*Hira* Congested mean (s.d) [24 samples]	*Hira* Free-flow mean (s.d) [54 samples]	*Adi* Congested mean (s.d) [27 samples]	*Adi* Free-flow mean (s.d) [27 samples]
70th perc. speed (kmph)	12.2 (4.0)	18.2 (6.2)	7.7 (6.1)	21.1 (6.1)
Perc. speed < 10Kmph	65.6 (11.6)	51.1 (16.3)	79.5 (16.1)	37.6 (20.2)

Speed based metrics

Number of honks
direction insensitive
Duration of honks (secs) in 10 mins

Metric	*Hira* Congested mean (s.d) [24 samples]	*Hira* Free-flow mean (s.d) [30 samples]	*Adi* Congested mean (s.d) [27 samples]	*Adi* Free-flow mean (s.d) [27 samples]
Num. Honks	113 (30.4)	55.5 (21.1)	149.4 (27.8)	57.6 (21.2)
Honk duration (sec)	45.1 (12.4)	21.8 (9)	71.5 (21.4)	21.7 (9.2)

Non speed based metrics

Statistical divergence tests

Metric	Mann-Whitney U test *Hira*	Mann-Whitney U test *Adi*	Kolmogorov-Smirnov test *Hira*	Kolmogorov-Smirnov test *Adi*
70th perc. Speed	2.00E-006	7.48E-007	6.16E-005	4.48E-004
Perc. Speed < 10 Kmph	1.05E-005	2.28E-004	3.57E-006	5.95E-004
Num. Honks	5.33E-015	2.13E-014	3.30E-014	5.36E-019
Honk duration	3.86E-014	3.89E-014	6.19E-014	6.53E-017

p-values

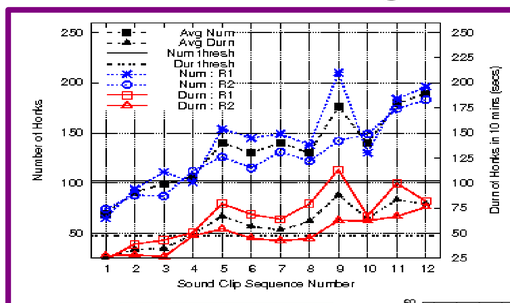
Statistical divergence of congested vs freeflowing data, based on all four metrics, is verified at 99.9% confidence using the Mann-Whitney U and two sample Kolmogorov-Smirnov tests.

Threshold based congestion detection

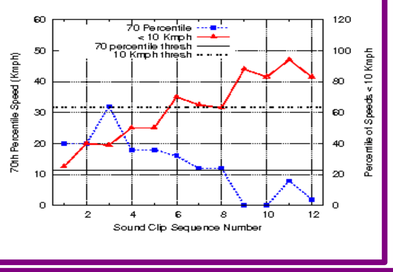
Metric	*Hira* Fp (%)	*Hira* Fn (%)	*Adi* Fp (%)	*Adi* Fn (%)
70th perc. Speed	24.1	8.3	12.1	5.6
Perc. Speed < 10Kmph	20.9	25.3	27.2	18.3
Num. Honks	10.7	17.4	0.0	5.9
Honk duration	7.1	19.6	0.0	5.9

Maximum false positive is 27.2% and maximum false negative is 25.3%

Freeflow To Congested : Transition



Continuous recording of road sound from 6 pm – 8 pm on 4th December, 2009, in Adi Shankaracharya Marg, showed transtion from freeflow to congestion, based on all four metrics.



5 Conclusion

Contributions

- Can handle *chaotic* traffic; higher the chaos, more is the amount of honking, better is the performance.
- Our algorithm gives fairly *accurate speeds* in practice.
- *Low cost*; each acoustic sensing unit will cost around $20.
- Two sample KS and MVU tests show statistical divergence of *congested and freeflow* states at 99% confidence level for each of the four metrics.
- Can differentiate traffic states in two *directions* on the same road.
- Can detect *onset of congestion*.

Future Work

- Deploying sensors for *automated data collection*.
- Planning *optimal sensor placement*.
- Developing algorithms for *real time data classification* based on historical values.
- Correlating data from various sensors to *estimate travel time*.
- Correlating data from consecutve sensor pairs to *estimate vehicle queue length*.
- *Designing mobile applications* to provide ITS.

Publications

- Rijurekha Sen, Vishal Sevani, Prashima Sharma, Zahir Koradia, Bhaskaran Raman, "Challenges In Communication Assisted Road Transportation Systems for Developing Regions", 3rd ACM Workshop on Networked Systems for Developing Regions, (NSDR'09), a workshop in SOSP'09, Montana, USA, 11 Oct, 2009.
- Rijurekha Sen, Bhaskaran Raman, Prashima Sharma, "Horn-Ok-Please", Mobisys'10 (under submission)