Nericell: Rich Monitoring of Road and Traffic Conditions using Mobile Smart-phones.

Prashanth Mohan (prmohan@microsoft.com)
Ramachandran Ramjee (ramjee@microsoft.com)
Venkata N. Padmanabhan (padmanab@microsoft.com)

Microsoft Research India, Bangalore

Objective

- Monitoring road and traffic conditions in a city
- Prior work has largely focused on the developed world, with its relatively simple traffic flow patterns.
- Address challenges including virtually reorientation and performing honk detection and localization in an energy efficient manner.

- A mobile phone-based approach to traffic monitoring is a good match for developing regions because it avoids the need for
  expensive and specialized traffic monitoring infrastructure.
  booming growth of mobile telephony in such regions.

What was done in this paper?

- Algorithms to virtually reorient a disoriented accelerometer along a canonical set of axes and then use simple threshold-based heuristics to detect bumps and potholes, and braking.

- Heuristics to identify honking by using audio samples sensed via the microphone.

- Evaluation of the use of cellular tower information in dense deployments in developing countries to perform energy-efficient localization.

- Triggered sensing techniques, wherein a low energy sensor is used to trigger the operation of a high energy sensor.

- Finally, we have implemented most of these techniques on smartphones running Windows Mobile 5.0.

Overview

- Annotate traffic maps with road conditions, noisiness and level of chaos in traffic.
- Traffic reports in map already available.
- Washington State SmartTrek system.

Hardware Requirements.

• Computing: CPU, operating system, and storage
that provides a programmable computing platform.

• Communication:
 Cellular: radio for basic cellular voice communication (e.g., GSM), available in all phones.
 Cellular data: e.g., GPRS, EDGE, UMTS, provided by the cellular radio.
 Local-area wireless: radios for local-area wireless communication (e.g., Bluetooth, WiFi).

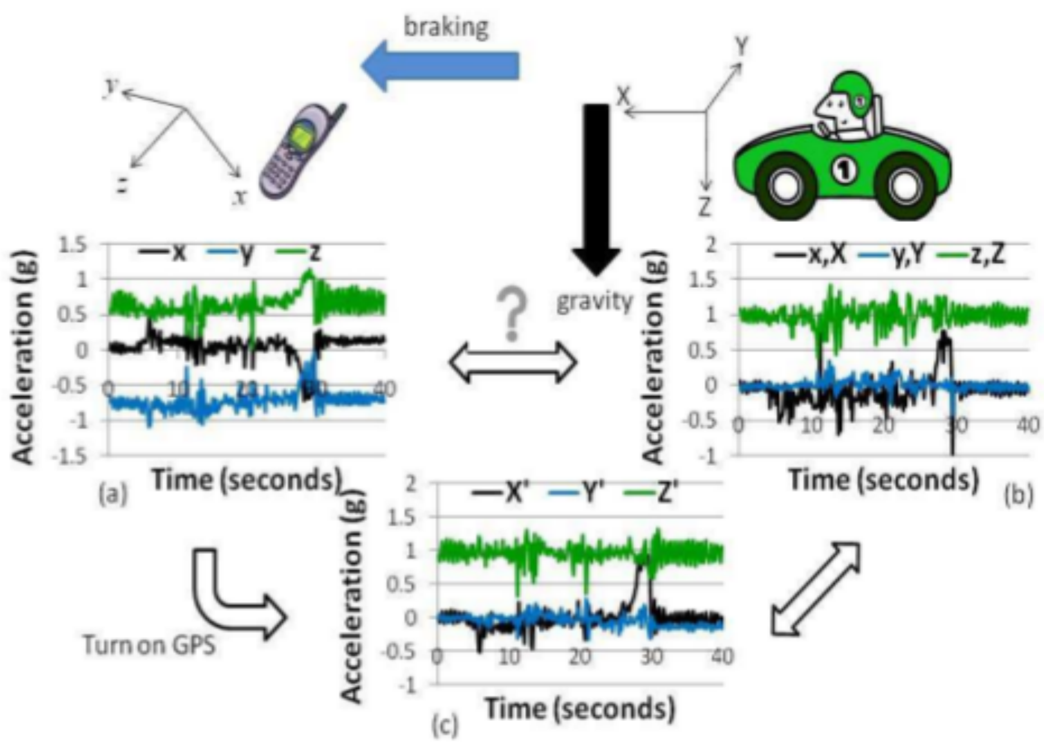
• Sensing:
 Audio: microphone.
 Localization: GPS receiver.
 Motion: accelerometer, sometimes included for functions such as gesture recognition.

Nericell does not require all participating phones to include each of these capabilities.

HP iPAQ hw6965, HTC Typhoon, Sparkfun WiTilt accelerometer.

ACCELERATION

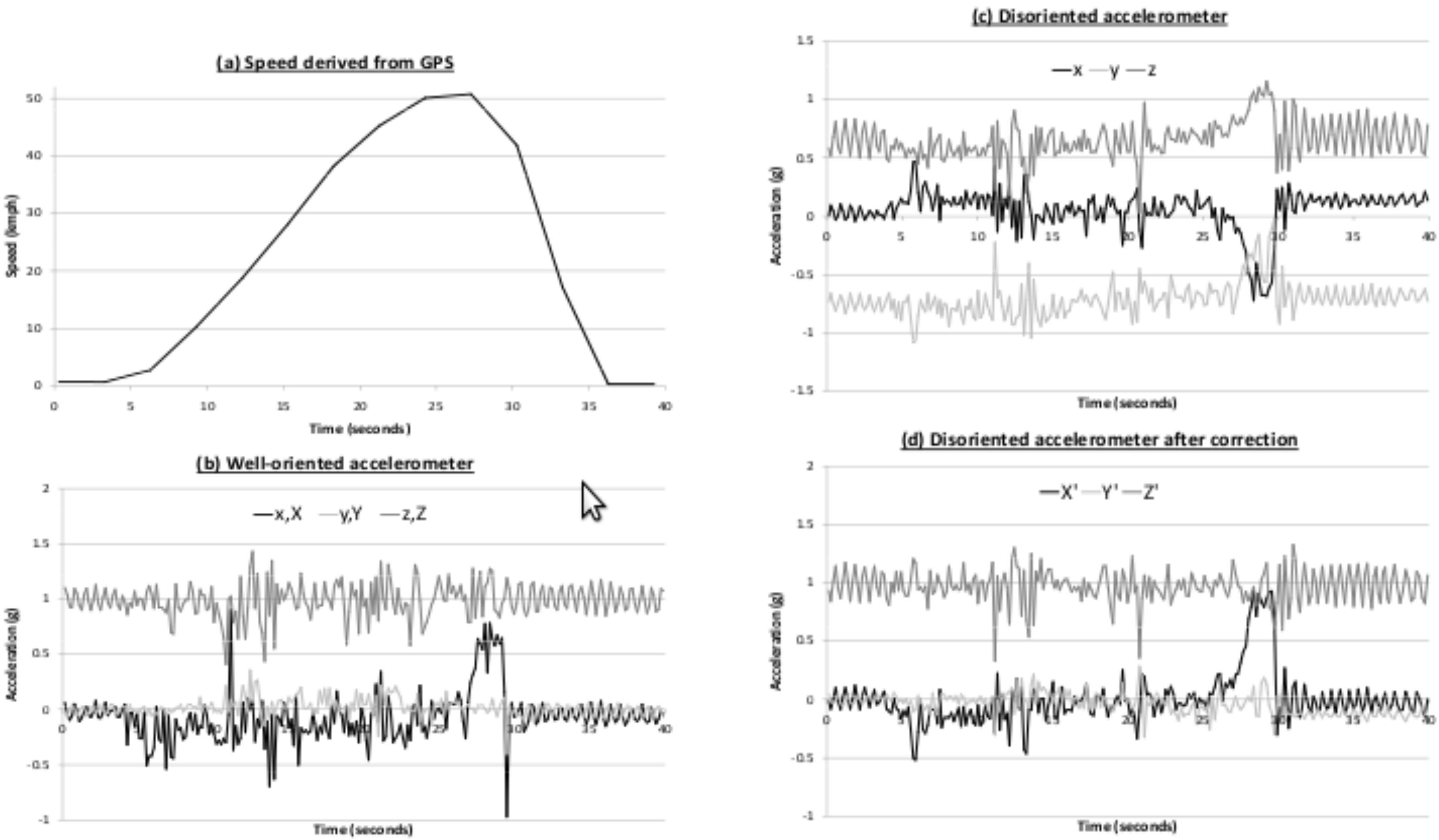
- 3 axis accelerometers.
- A Cartesian frame of reference.
- Disorientation can cause wrong inference.
- If disoriented, has to be virtually reoriented.



Accelerometer Reorientation

- Orientation is represented by pre-rotation of Φ_{pre} about Z, followed by a tilt of θ_{tilt} about Y, and then a post-rotation of ψ_{post} again about Z.

Accelerometer



Detection.

User Interaction : The system tries to detect any user activity by looking for key Strokes, mouse movements, calls etc.

Road Conditions : Break detection, Bump detection, Noise detection, Geo location.

Braking Detection

- Breaking is easier to detect than movement.
- Using Accelerometer, GPS based is difficult.
- Accelerometer experiences a force pushing it to the front.
- GPS based : works over a short span.
- GPS ground truth : Average (minimum) speed decrease over four seconds, 12 kmph.
- Stop&Go traffic vs Pedestrian.
- Pedestrian : No sustained surges.

Break detection

Accelerometer (threshold T (g))	False Negative		False Positive	
	Rate	Change in speed avg(max)	Rate	Change in speed avg(min)
ACL-1 (T=0.11)	4.4%	15(16)	22.2%	12(10)
ACL-1 (T=0.12)	11.1%	16(18)	15.5%	12(9)
ACL-3 (T=0.11)	4.4%	15(16)	31.1%	12(9)
ACL-3 (T=0.12)	11.1%	16(18)	17.7%	12(9)

Table 4: False Positives/Negatives of Brake detector

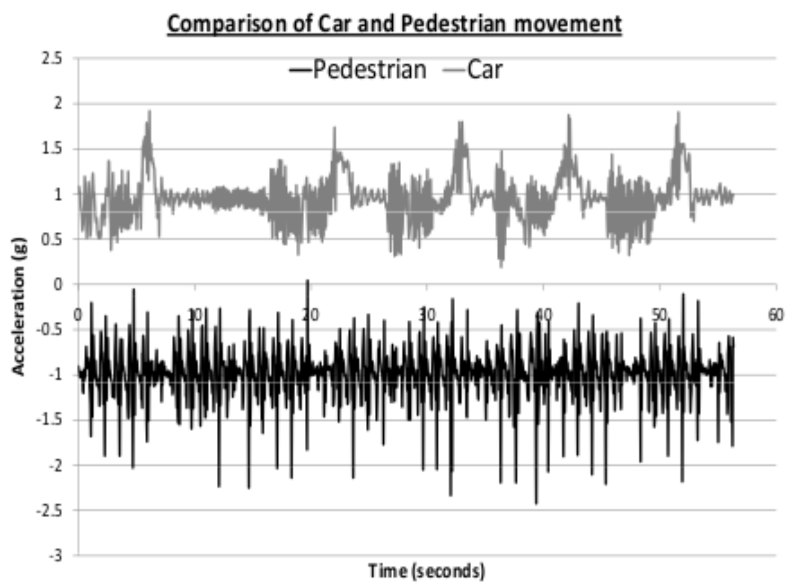


Figure 5: X-axis accel. for a car in traffic and a pedestrian

Bump Detection.

- One of the main features of Nericell.
- A major problem.
- Intentional and non Intentional.
- Establishing ground truth, subjective.
- Small dips can cause many false positives.

Challenges

Accelerometer readings at different speeds.

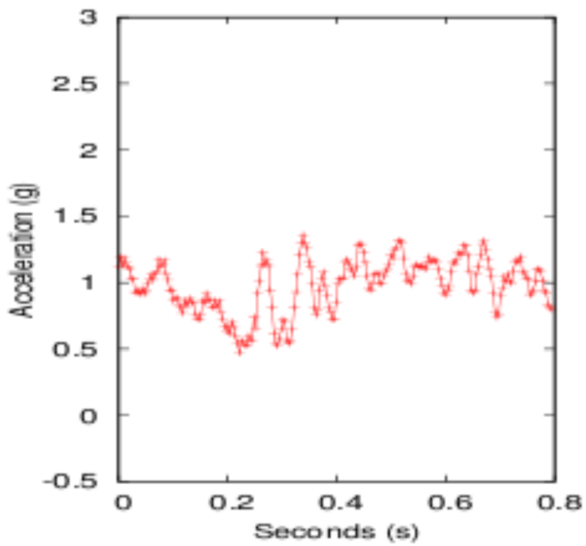


Figure 6: a_Z **when traversing a bump at low speed**

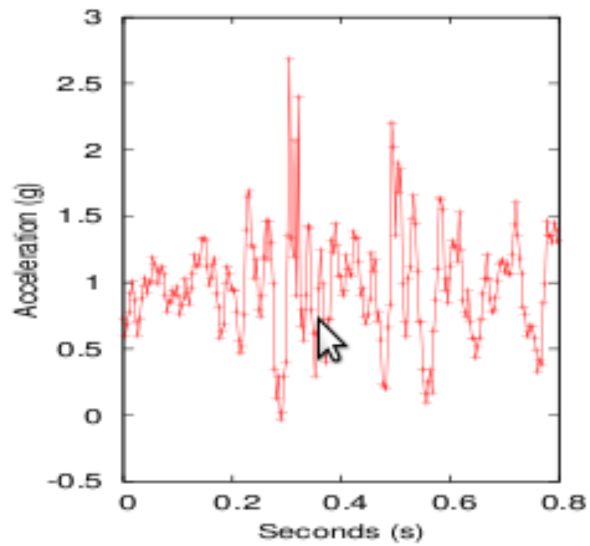


Figure 7: a_Z **when traversing a bump at high speed**

Bump Detection.

- Used 2 bump detectors. Z-peak & Z-sus.
- Z-peak used at high speeds.
- z-sus looks for a sustained dip in aZ, used at low speeds.
- Z-sus looks for a sustained dip of at least 20 ms.
- Tested over 2 drives, 5km – 44 bumps and 30Km 101 bumps. T_{sus} = .8g.
- Difficulty of establishing the ground truth

Bump Detection – Performance.

Detector	Accel.	Speed $<$ 25kmph		Speed $\geq$ 25kmph	
		FN	FP	FN	FP
BUMPY road		40 bumps total		4 bumps total	
z-sus	ACL-1	**25%**	**5%**	50%	0%
	ACL-2	**30%**	**0%**	25%	0%
	ACL-3	**23%**	**5%**	0%	50%
z-peak (1.45)	ACL-1	28%	15%	0%	125%
	ACL-2	20%	5%	0%	125%
	ACL-3	30%	10%	0%	200%
MIXED road		62 bumps total		39 bumps total	
z-sus	ACL-1	**29%**	**8%**	18%	80%
	ACL-3	**37%**	**14%**	0%	136%
z-peak (1.45)	ACL-1	35%	6%	5%	197%
	ACL-3	65%	21%	3%	49%
z-peak (1.75)	ACL-1	90%	0%	**51%**	**3%**
	ACL-3	83%	0%	**41%**	**8%**

Table 5: False positives/negatives (FP/FN) for bump detectors, *z-peak* and our new *z-sus*. The numbers in bold correspond to the hybrid approach of applying *z-sus* at low speeds and *z-peak* at high speeds.

Audio sensing.

- Noise detection to check for honks and other extraneous sound.
- Audio data never leaves the phone – privacy.
- Bad approach - look for spikes in sound power levels.
-

Honk Heuristic.

- The heuristic used classifies a sound as a Honk as long as there are at least two spikes, including at least one spike in the 2.5 kHz to 4 kHz region corresponding to the region of highest human ear sensitivity.

Phone	Exposed vehicle		Enclosed vehicle	
	FP	FN	FP	FN
KJAM (T=5)	38%	0%	8%	15%
KJAM (T=7)	0%	0%	0%	23%
KJAM (T=10)	0%	19%	0%	54%
iPAQ (T=5)	19%	4%	0%	19%
iPAQ (T=7)	0%	8%	0%	50%
iPAQ (T=10)	0%	27%	0%	81%

Table 6: False Positives/Negatives (FP/FN) of Honk detector

Localization.

- Using GSM radios
- GSM signal strength-based localization algorithms can be quite accurate
- Seattle – Bangalore.
- Strongest signal (SS)-based localization algorithm

TRIGGERED SENSING

- Low Energy - GSM radio and the accelerometer
- High Energy - GPS and the microphone
- GSM – GPS triggering.
- Virtual reorientation.
- Honk - Braking detection

Power Consumption Chart.

	Power (mW)	% Time active
Audio	223.2	5
Honk Detection	63.3	5
GPS	617.3	10
Reorientation of accel values	20.9	100
Bump & Brake Detection	9.3	100
Accelerometer	1.65	100

Table 8: Energy requirement of Nericell during a drive

Critique.

- Does not seem very convincing.
- Not a device but more of a proof of concept.
- Not integrated into one device. Spread all over.
- Not universally applicable.

Side-note

Not relevant but cool.

AutoParking
http://www.youtube.com/watch?v=88oOW1zx5Xg

Car driven by iPhone
http://www.youtube.com/watch?v=oHDwKT564Kk

References.

- Freescale MMA7260Q Accelerometer. http://www.sparkfun.com/datasheets/Accelerometers/MMA7260Q-Rev1.pdf
- INRIX Dynamic Predictive Traffic. http://www.inrix.com/technology.asp.
- Intelligent Transportation Systems. http://www.its.dot.gov/.