RoadMic: Road Surface Monitoring using Vehicular Sensor Networks with Microphones

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ESF grants:
2009/0219/1DP/1.1.1.2.0/APIA/VIAA/020
R&D Center for Smart Sensors and Networked Embedded Systems
2009/0138/1DP/1.1.2.1.2/09/IPIA/VIAA/004
Support for Doctoral Studies at the University of Latvia

NDT 2010, Charles University, Prague, Czech Republic, 08.07.2010

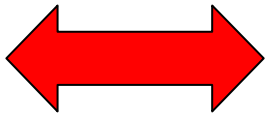
Research area and motivation

- Five levels of car driving
  - manual driving
  - **assisted driving (our primary research area)**
  - **semi automatic driving (our secondary research area)**
  - highly automatic driving
  - fully autonomus driving

- Parties interested in road surface monitoring
  - car users
    - personal cars
    - public transportation
  - road maintainers

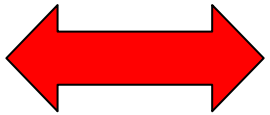
State of the art

- Scientific projects (data acquisition)
  - BikeNet (Dartmouth College)
  - Pothole Patrol (MIT)
  - SoundSense (Dartmouth College)
  - Nericell (Microsoft Research India)



specific hardware components (accelerometers)

- WEB resources (data presentation)
  - http://potholes.co.uk
  - http://bedrukarte.lv



manual data reporting (WEB forms)

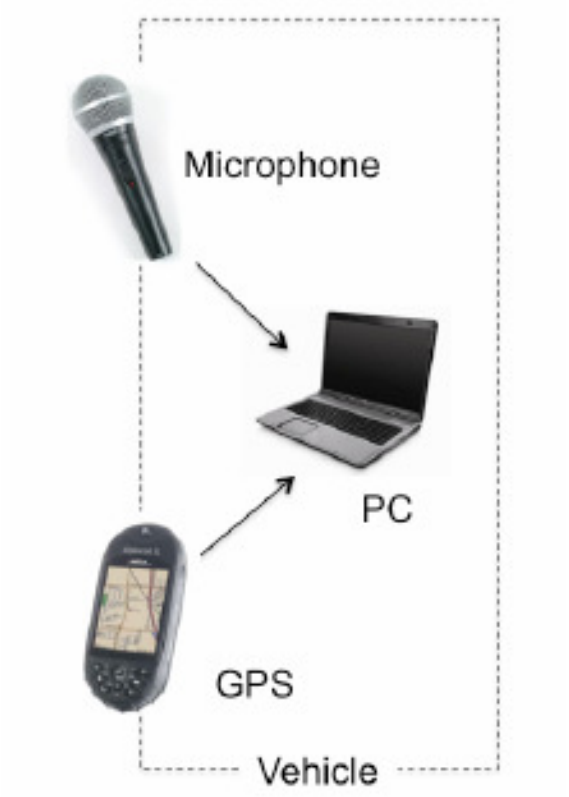
Research problem

- What data quality in terms of road surface quality could be achieved by recording and processing sound in a moving vehicle using regular off the shelf audio microphones?

- Is this approach generic and usable for diverse event detection using different sensors?

System requirements

- Low setup and maintenance costs
- Availability of used hardware components
- General-purpose computer for data logging
- Wide range of supported sensors in addition to the microphone
- Localization service for data geo-tagging
- Software platform independence



Vehicle on-board sensing system architecture

Algorithm

	Mandatory	Online
• Record GPS trace and sound simultaneously	✓	✓
• Interpolate position between two GPS fixes, which typically have a granularity of one second	✗	✗
• Discretize the sound signal with lower frequency to reduce sample count, high frequencies usually contain no information and can be discarded as noise	✗	✗
• Assign geographical coordinates for sound fragments, which also represent a small geographical region	✓	✗
• Perform event detection function for each region, using digital signal processing (DSP) which is specific for each class of events	✓	✗
• Create map with points of interest representing detected events	✓	✗

Setup

Evaluation I

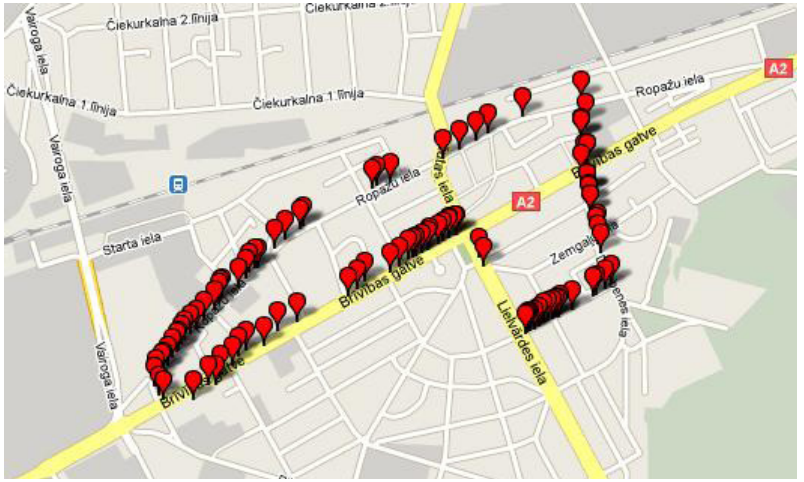
- Hypothesis
  - recorded sound has a correlation with road surface irregularities
- First impression
  - particular road segment with pothole
  - sound recorded while driving along it
  - footprint of high amplitude of low frequency oscillations

First examined road segment with pothole

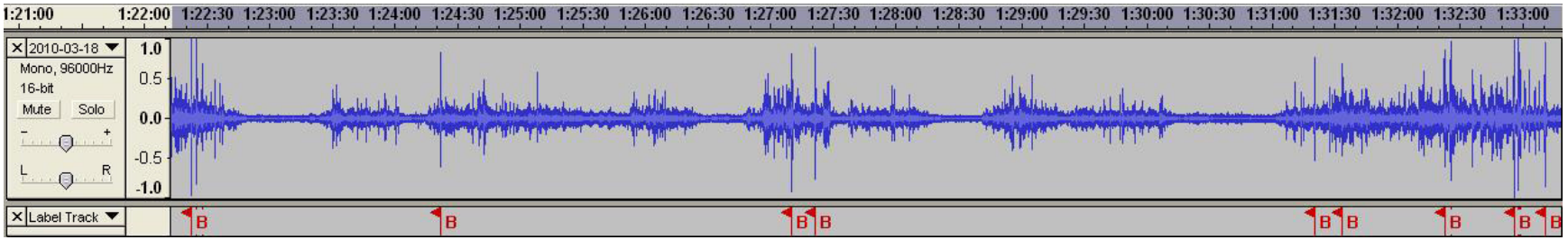
Sound of test segment with pothole position marked

Evaluation II

- Ground truth
- Five rough classes
  - large potholes (3)
  - small potholes (18)
  - pothole clusters (30)
  - drain pits (29)
  - gaps (25)
- Ten test drives
- Thresholding by amplitude



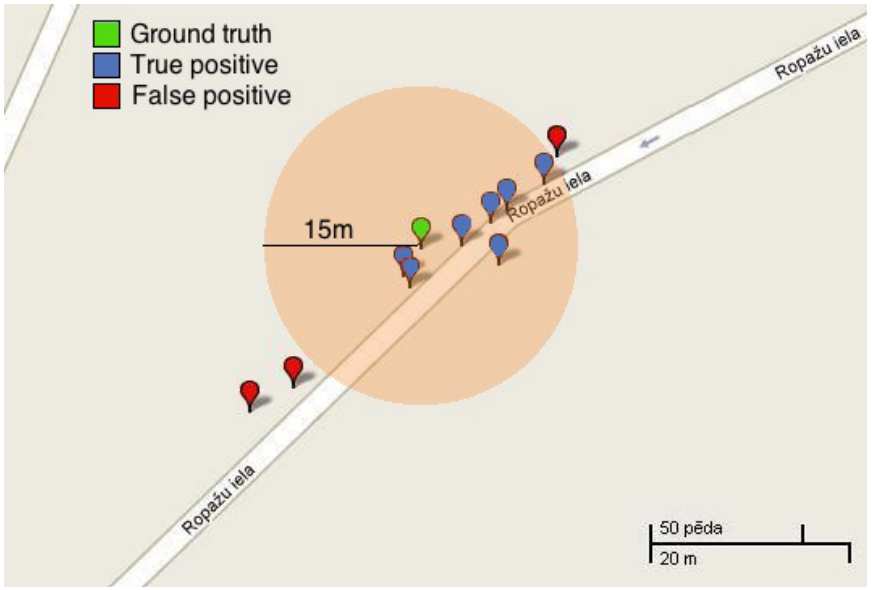
Experimental test track, 4.4km long, with manually marked road roughs



Sound of one test lap with detected pothole positions using 50% threshold

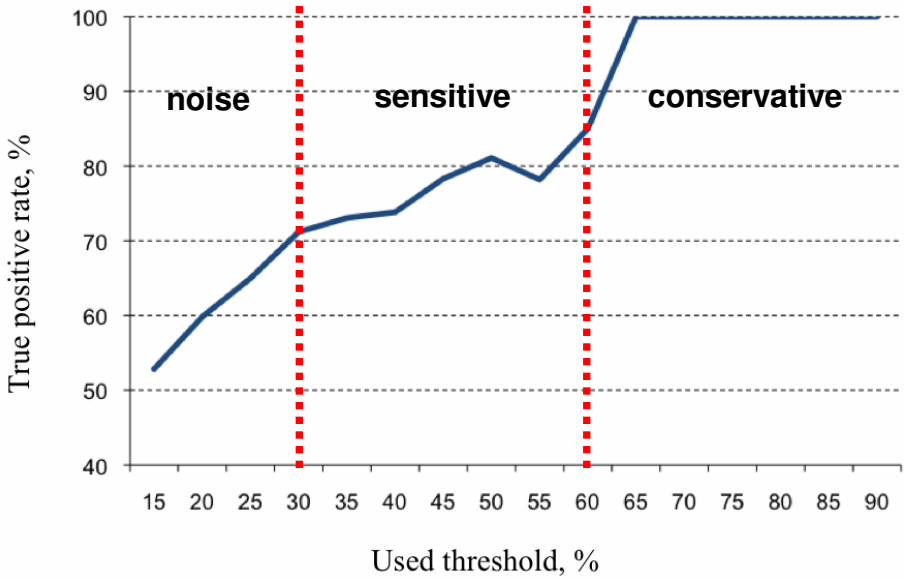
Evaluation III

- Accuracy limitations
  - GPS precision
  - car speed



Pothole positions detected using sound analysis around position marked as ground truth. Positions not further than 15m are considered true positives

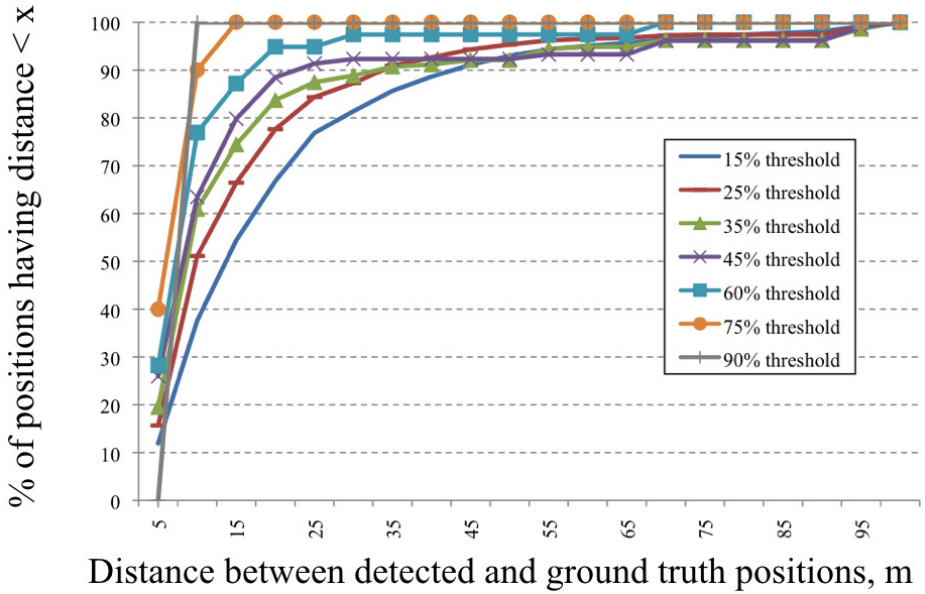
- Different threshold levels
  - noise (<30%)
  - sensitive (30-60%)
  - conservative (>60%)



True positive rate by each threshold. Thresholds above 60% give 100% true positives

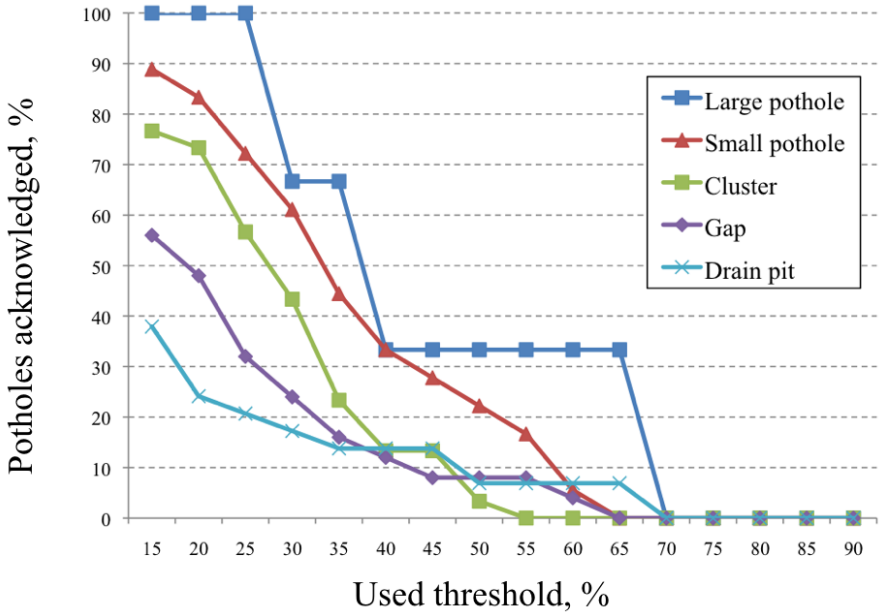
Evaluation IV

- distances between detected and ground truth positions



Distribution function of distances between detected positions and ground truth, using thresholds 15-90%. Thresholds above 30% give < 20m accuracy with > 80% credibility

- **acknowledgement criterion:**
  - ground truth position is considered as acknowledged by our algorithm if it has at least 4 true positives in the total 10-drive test data set

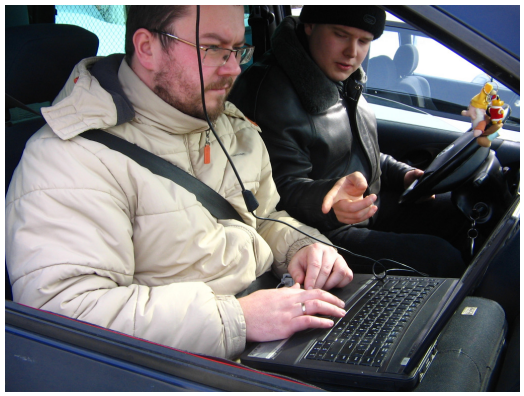


Fraction of ground truth potholes acknowledged by our algorithm, using different thresholds for sound signal analysis

- Thank you for your attention!

- Some pictures from our field experiments:

Example of pothole cluster



Configuration before test drive

This is NOT a pothole ☺

- Now it is time for questions and discussion...