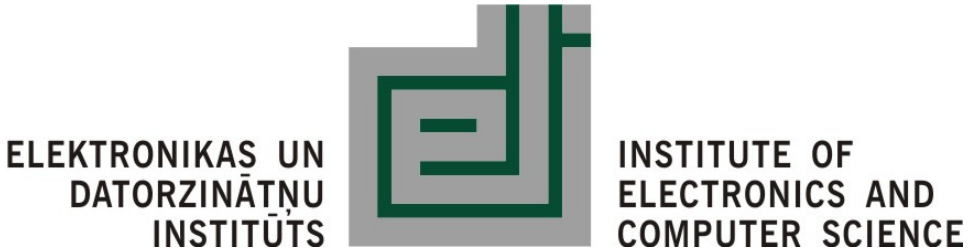

Vehicle counting and motion direction detection using microphone array

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IEGULDĪJUMS TAVĀ NĀKOTNĒ

Multifunctional intelligent transportation system point technology
Nr.2010/0250/2DP/2.1.1.1.0/10/APIA/VIAA/086

Motivation

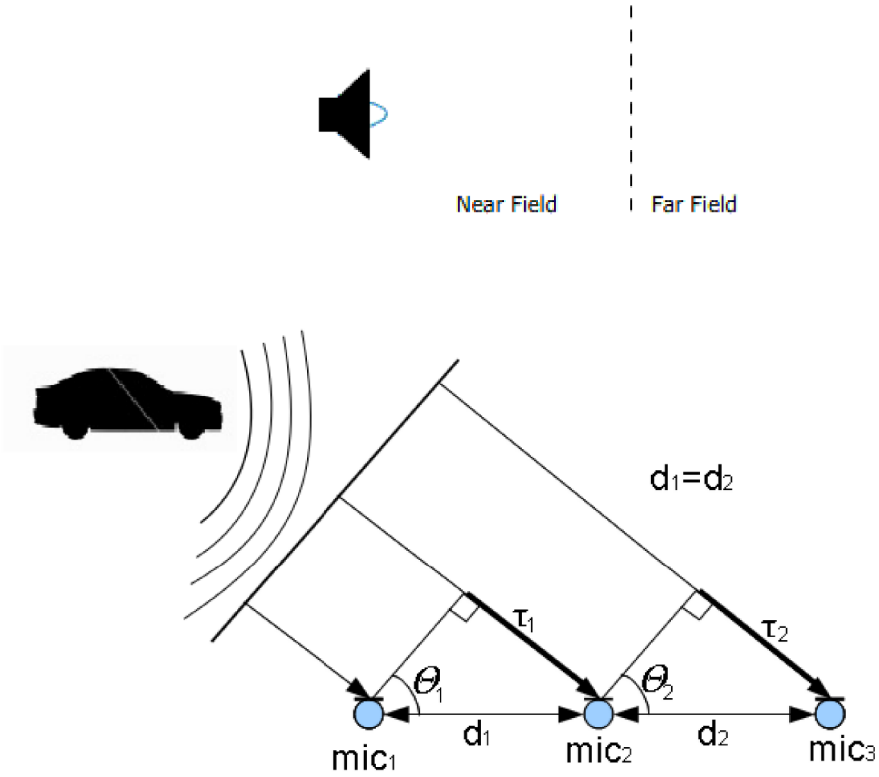
- Need of vehicle detection for traffic statistics
- Non-invasive sensors
- Goal - efficient traffic management

Vehicle detection

- Vehicle can be detected by it
  - Appearance (video camera, laser sensor)
  - **Sound (microphone array)**
  - Heat (PIR sensor)
  - Metal body and engine (magnetometer, induction loop)
  - Weight (pressure sensors)

Microphone array

- Any moving motor vehicle creates noise
- Applying microphone arrays and using signal processing it's possible to extract information from obtained signals
- Far-field approximation is applied
- Generalized cross-correlation(GCC) algorithm is used for delay estimation between two microphones

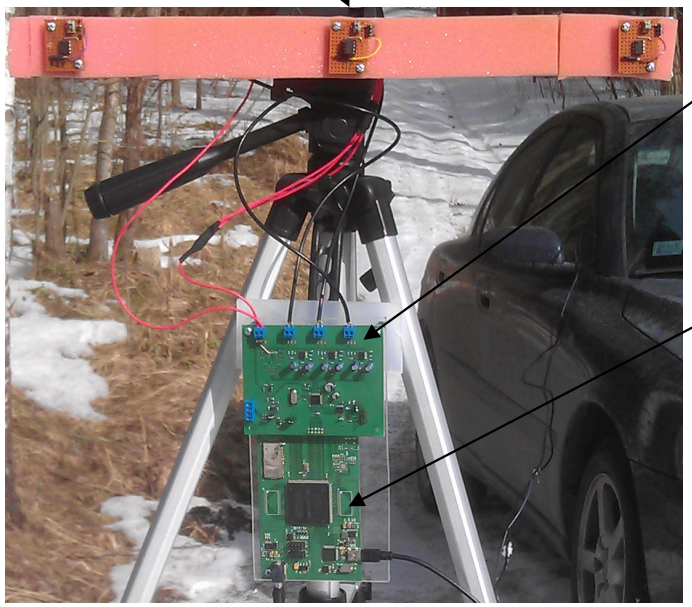


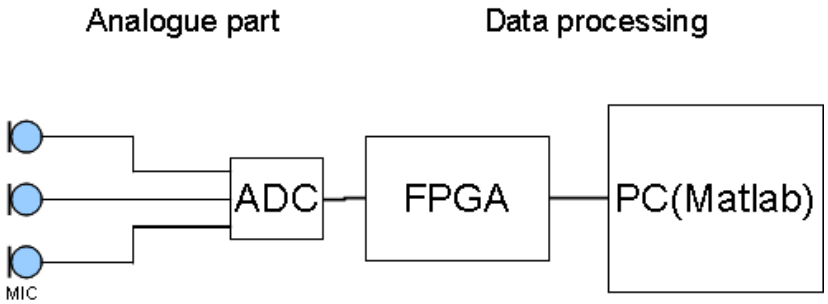
Designed system hardware

MEMS microphones

AD1974 audio ADC
sampling frequency
48kHz

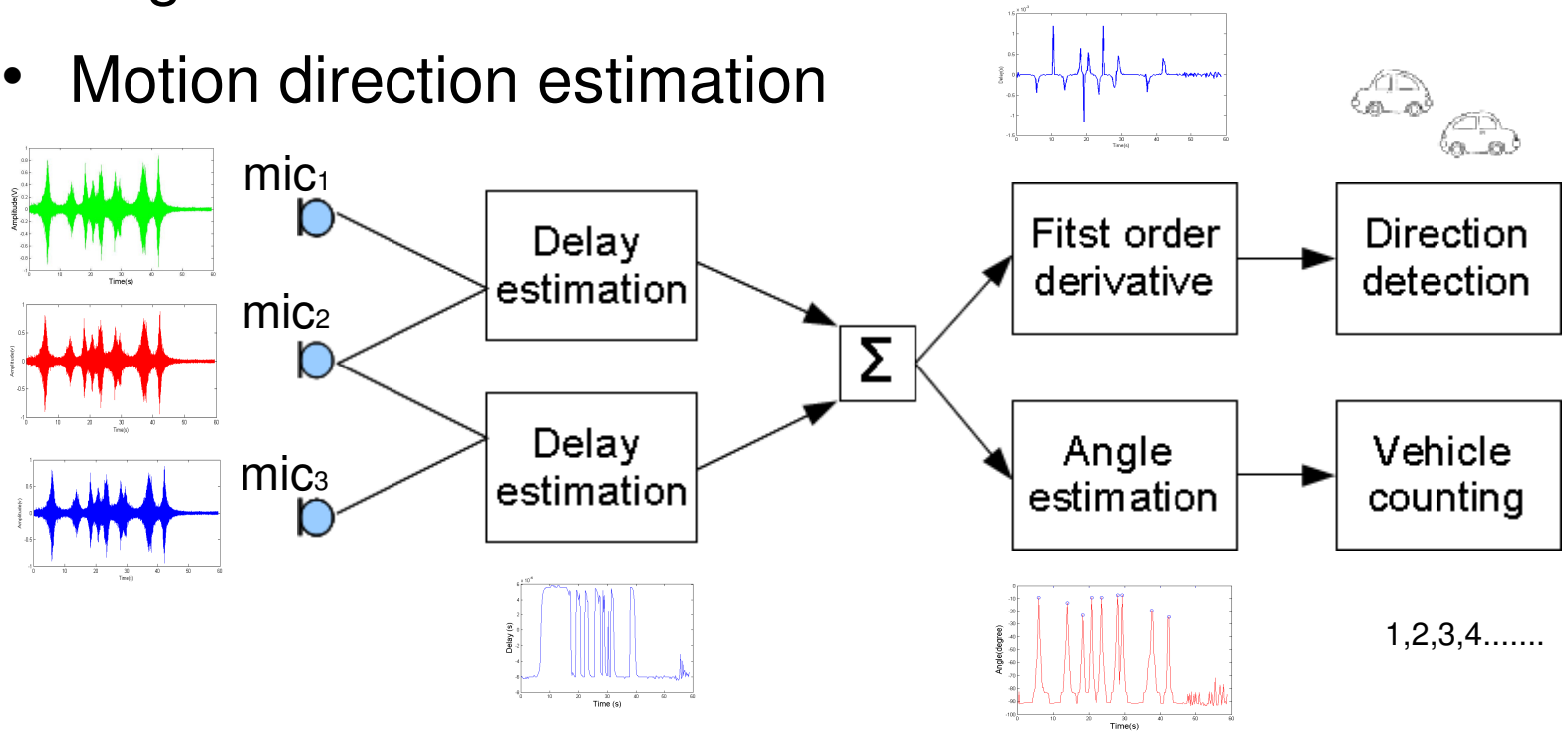
FPGA





Designed system algorithm

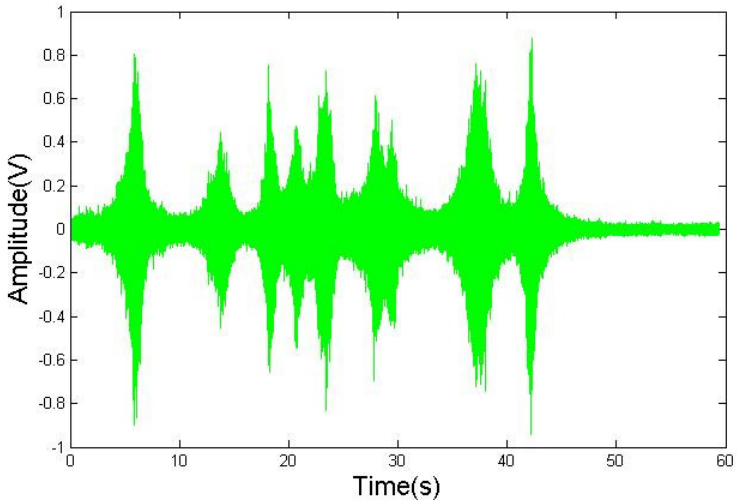
- Sound recording
- Delay estimation (windows length 250ms)
- Angle estimation
- Motion direction estimation



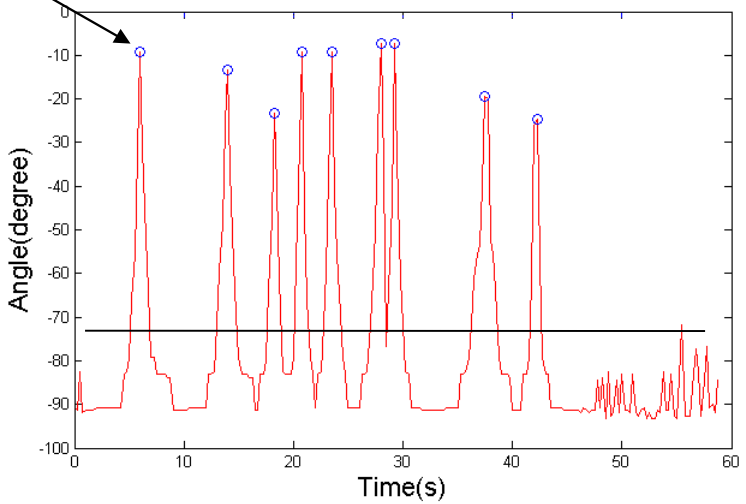
Vehicle counting

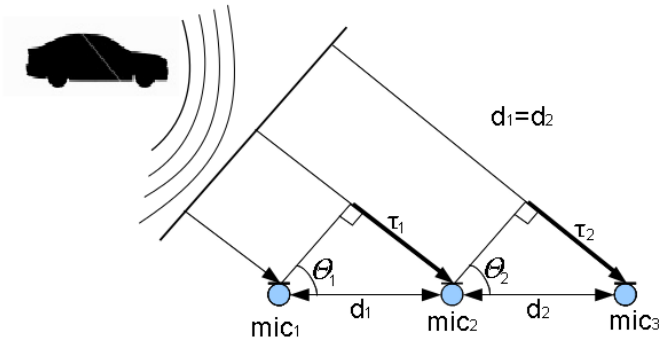
Angle values are estimated based on derived delays. Threshold is applied to filter noisy values. Nearest peak neighbor analysis is used to eliminate unwanted noise.

Sound signal from 9 vehicles



Detected vehicles



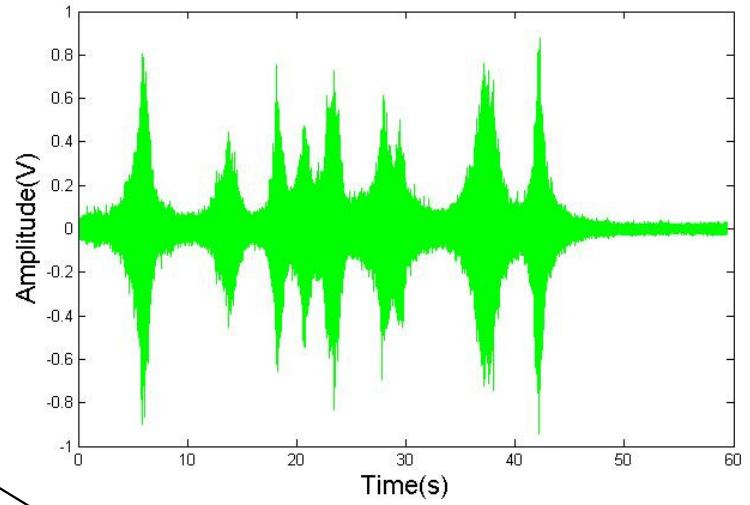


$$\theta = \sin^{-1}\frac{\tau \cdot c}{d}$$

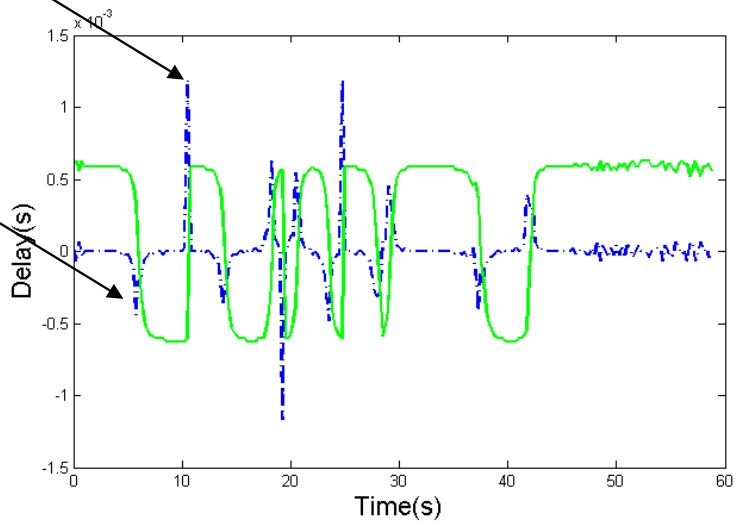
c - speed of sound 343m/s
d - distance between microphones(20cm)
τ - time delay

Motion direction detection

First order derivative is calculated from obtained delays. It represents slope of delays. Peaks are analyzed and compared based on their height.

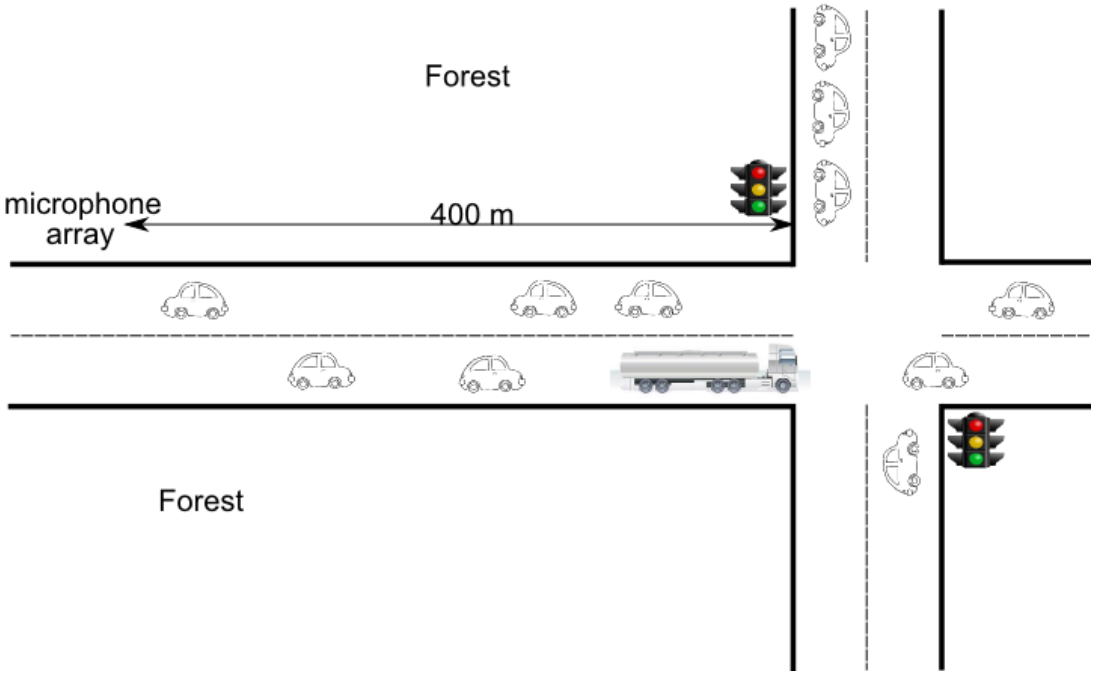


Maximums and minimums of derivative



Motion direction precision is ~70%

Tests in real traffic flow



	Vehicle count	Precision
Ground truth	871	100%
False positive	119	13,66 %
False negative	84	9,64 %

Thank you for your attention!