Detecting, Localizing, and Tracking Alarm Signals in Traffic using a Microphone Array

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Within the AAL project “Intelligible City For All”
Project Milestones

Proof of concept for passive acoustic alarm signal localization on a moving vehicle

- Hardware development (microphone array, carglass microphones)
- Database of recordings (alarm car maneuvers, ego noise)
- Algorithm selection / development
- Software prototype implementation
- Evaluation on test data
- Human-Machine-Interface development
Developed Hardware

Wind-protected microphones / carglass microphones (work in progress)

- Renault Scenic II front left door
- Sealing and damping rubber
- Door can rotate on hinges
- Fixed to a rolling structure
- 12V door opening
- DC motor
Database of recordings

Separate recordings of scenarios and disturbances

Alarm signals
- Police, Ambulance & Firefighters
- IT / FR / DE / AT

Alarm car maneuvers
- Lateral pass-by (e.g. straight road)
- Front pass-by (e.g. intersection)
- Circular pass-by (omnidirectionality test)

Ego noise (open and closed windows)
- 30 km/h
- 50 km/h
- 70 km/h
- 90 km/h

Superposition of signal recordings and noise for evaluation
Spectral distribution

Alarm signal (French firefighters at 30m distance) is partly masked by ego noise
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Project Partners

Task: I’City Alarm – Array Signal Processing

Collaborating partners

• ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)
• UPD/ LinkLab (Université Paris-Descartes / TELNET CEA-Linklab Tunisie)
• TUM (Technische Universität München)

Task dissemination

• Detection/ Identification: ENEA/UPD
• Localization: ENEA/TUM
• Tracking: ENEA/TUM
Alarm Signal Detection

Initializes the processing chain

Current concept:
• Use the a priori known alarm signal specifications
• Several detection methods
  – Detect the fundamental frequency and harmonics in the signal with filterbanks
  – Short-Time-Fourier-Transform masks
  – Pulse detection in the STFT domain
• Binary decision (Alarm present or not)
• Alarm type recognition

Future development
• Signal-independent detection via tonal analysis
Alarm Signal Localization

Assumptions and concepts

Model assumptions
- 1D geometry (azimuth angle in cylindrical coordinates)
- Direct line-of-sight
- Free-field conditions (no reverberation)
- One source at a time

Steered beamforming approach (Delay-And-Sum-Beamformer / SRP-PHAT)
- Realtime processing
- Sufficient angular resolution (actually required resolution depends on HMI)
- Multiple sources can be detected

Signal characteristics well-known
- Evaluate significant frequency range only
Alarm Signal Tracking

Post processing

Goal: Stable direction estimate from noisy localization output

Particle filtering
Preliminary Localization Results

Example scenario: Lateral pass-by

Experimental Setup

Localization result (DSB) without additive noise, frequency range: 600Hz – 4kHz
Preliminary Localization Results

Lateral pass-by scenario with ego noise (urban traffic speed)

30 km/h noise added

50 km/h noise added
Preliminary Localization Results

Lateral pass-by scenario with ego noise (overland speed)

70 km/h noise added

90 km/h noise added
Conclusion

How promising is such a system?

As an early warning system
- at low speed (urban traffic)
- in good conditions (little reverberation)
- Need further comparison against human drivers

As an immediate warning system (~3-5 seconds TTC)
- Signal is always detected if distance goes below 50m and direct line-of sight
- Valuable warning system for presbyacusic people
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