Auralisation de trafics routiers non-stationnaires en milieu urbain basée sur une synthèse granulaire temps réel

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✓ Context
✓ Auralization framework
  ✓ Overview
  ✓ Source signal synthesis
✓ Quantitative validation
  ✓ Approach
  ✓ Results
✓ Audio samples
✓ Conclusions
Perceptive evaluation of noise pollution

✓ Analyse (engineers) or facilitate awareness (decision makers) of noise pollution
✓ Extend standard tools based on sound pressure levels only
✓ Make acoustic simulation results ‘audible’

✓ Requirements
  ✓ Render a close version of the real sound field
  ✓ Provide user interaction for comparative listening tests

✓ Challenge
  ✓ Satisfy both physical accuracy and user interaction with limited computational resources
✓ Novel approach for the auralization of non-stationary road traffic noise
✓ 3 main tasks:
  ✓ synthesis of source signals (engine and rolling noise for varying speed)
  ✓ modeling of sound propagation
  ✓ spatial audio rendering

Auralization framework
Overview

Off-line processing

Rolling/engine noise recording & analysis

Rolling/engine noise database

Site modeling

Calculation of acoustic paths

Traffic flow module

Vehicle (position, speed, acceleration) time dependent

Rolling/engine noise synthesis

Moving source auralization

Real time processing

Listener position
Auralization framework
Source signal synthesis

- Engine noise recording at varying rpm (vehicle at rest)
- Rolling noise recording at varying speed (CPX method)

**GRANULAR SYNTHESIS FRAMEWORK**

**OFF-LINE ANALYSIS**
- Source signal recording
- Estimation of control parameter evolution
- Extraction marks location
- Sound sample extraction

**REAL TIME SYNTHESIS**
- Control parameter target values
- Sound sample selection
- Overlap-and-add processing
Auralization framework
Source signal synthesis (cont’d)

Sample Overlap-And-Add for real time synthesis

Engine noise: Synchronous synthesis
(1 sample = 1 full engine cycle)

Rolling noise: Asynchronous synthesis
Source signals represent equivalent source in free field at 1 m
Constant calibration gain applied to extracted sound samples
Based on the Harmonoise vehicle emission model according to

Rolling noise calibration gain

\[ G_{R,\text{cal}} = 10 \log_{10} \left( \sum_{i=1}^{M} \left(10^{(E_{R}(v_i) - L_{WR,A}(v_i)) / 10} \right) P(v_i) \right) \]

Engine noise calibration gain

\[ G_{P,\text{cal}} = 10 \log_{10} \left( \sum_{i=1}^{M} \left(10^{(E_{P}(v_i) - L_{WP,A}(v_i)) / 10} \right) P(v_i) \right) \]

Where

- \( L_{WR,A}(v_i) \) reference rolling noise power in dB(A) at speed \( v_i \)
- \( L_{WP,A}(v_i) \) reference engine noise power in dB(A) at speed \( v_i \)
- \( P(v_i) \) probability of occurrence of speed \( v_i \)
- \( E_{R}(v_i) \) energy in dB(A) of synthesized rolling noise signal at speed \( v_i \)
- \( E_{P}(v_i, l) \) averaged energy in dB(A) of synthesized engine noise at speed \( v_i \)
- \( E_{P}(v_i, g) \) energy in dB(A) of synthesized engine noise signal at speed \( v_i \) and gear \( g \)
- \( P(g, v_i) \) probability of driving at gear \( g \) for speed \( v_i \)
Quantitative validation

Approach

- Compare sound pressure levels of auralized and recorded sequences
- Single vehicles passing by the listening point at different speeds
- Straight road in open field
- 5 vehicles / 3 speeds
- Measure SPL + speed
- Binaural / Stereo recordings
Engine and rolling noise dataset from CPX recording on same road / vehicles

Site modeling
(approximate terrain data and ground properties)

Auralization

Signal analysis
(Leq, Lamax, …)

Listening tests
Quantitative validation
Results

BMW 320

Volkswagen Golf

Volkswagen Transporter
Quantitative validation
Results (cont’d)

BMW 320 – LAFeq vs Time

BMW320 30kmh 2140rpm

BMW320 76kmh 2280rpm
Quantitative validation
Audio samples

BMW 320 - 76 km/h - 2280 rpm
Quantitative validation
Audio samples (cont’d)

Golf - 88 km/h - 1580 rpm

Audio samples (cont’d)
Golf - 88 km/h - 1580 rpm
Quantitative validation
Audio samples (cont’d)

Transporter - 37 km/h - 2340 rpm

recorded

auralized

Time (s)
Frequency (Hz)
recorded
auralized

0 5 10 15
0 5 10 15

-140 -120 -100 -80 -60 -40 -20
-140 -120 -100 -80 -60 -40 -20

JTAV 2012    |   Auralization of non-stationary traffic noise
Audio samples
Real traffic in urban site

- Two lane road
- Two stop lights
- 800 vehicles per hour
- Averaged speed = 47 km/h

Auralized traffic
Auralized vs recorded
Conclusion and perspectives

✓ New approach for the auralization of road traffic noise
  ✓ Real time auralization
  ✓ Non-stationary traffic flows with varying vehicle speed

✓ First quantitative results for
  ✓ Single vehicles / constant speed / receiver close to road
  ✓ Good agreement between SPL of recorded and auralized sequences

✓ Current work:
  ✓ Perceptual analysis of auralized sequences
  ✓ Quantitative and perceptual validation extended to
    ✓ non-stationary traffic conditions
    ✓ more complex urban site
✓ This research has been undertaken in the frame of the European project number 234306 HOSANNA

✓ Müller-BBM participated in the measurement campaign and provided the pass-by SPL data and tire noise CPX recordings