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

10 Octobre / JTAV 2012

Julien Maillard
Département Acoustique et Eclairage
Centre Scientifique et Technique du Bâtiment (CSTB)
Université Paris-Est

Outline

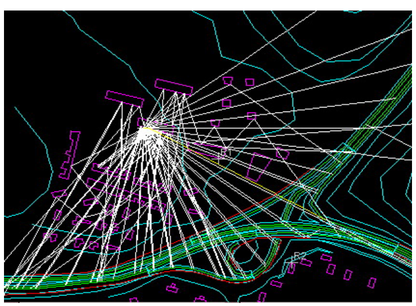
- ✓ Context
- ✓ Auralization framework
  - ✓ Overview
  - ✓ Source signal synthesis
- ✓ Quantitative validation
  - ✓ Approach
  - ✓ Results
- ✓ Audio samples
- ✓ Conclusions

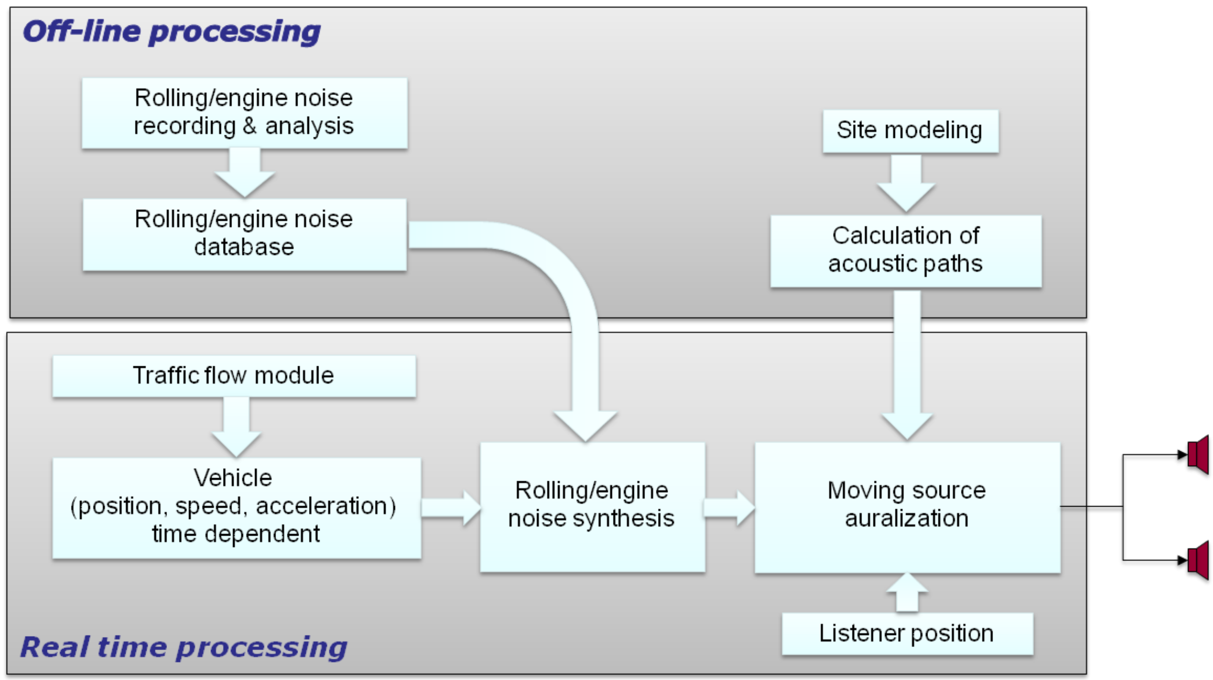
Context
Perceptive evaluation of noise pollution

- ✓ 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 ressources

Auralization framework
Overview

- ✓ 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
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

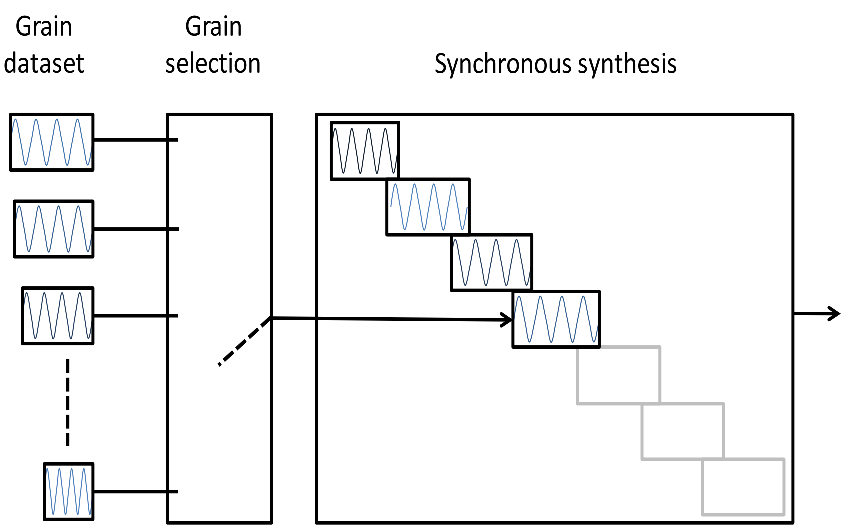
REAL TIME SYNTHESIS

Control parameter target values
↓
Sound sample selection
↓
Overlap-and-add processing

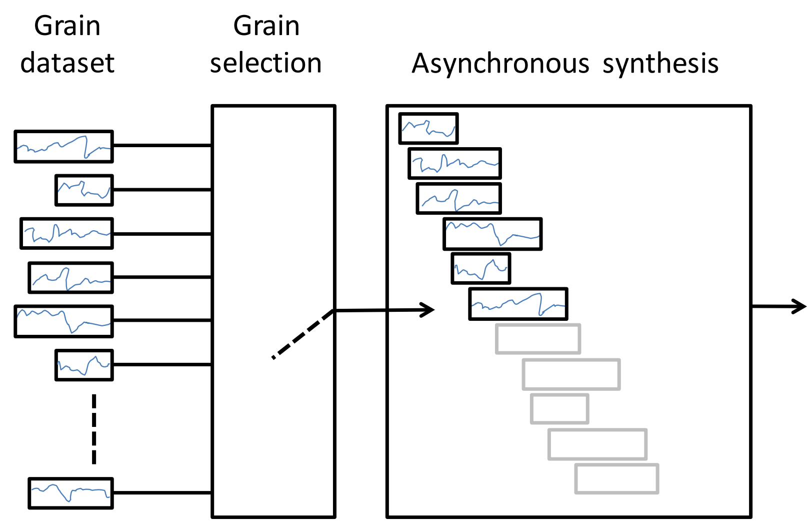
Auralization framework
Source signal synthesis (cont'd)

Sample Overlap-And-Add for real time synthesis

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



Rolling noise: Asynchronous synthesis



Auralization framework
Source signal calibration

- ✓ 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

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

Engine noise calibration gain

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

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

$P(v_i)$ propability of occurrence of speed v_i

$E_R(v_i)$ energy in dB(A) of synthesized rolling noise signal at speed v_i

$E_P(v_i) = 10log_{10}\left(\sum_{g=2}^{5}\left(10^{E_P(v_i,g)/10}\right)P(g,v_i)\right)$ 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

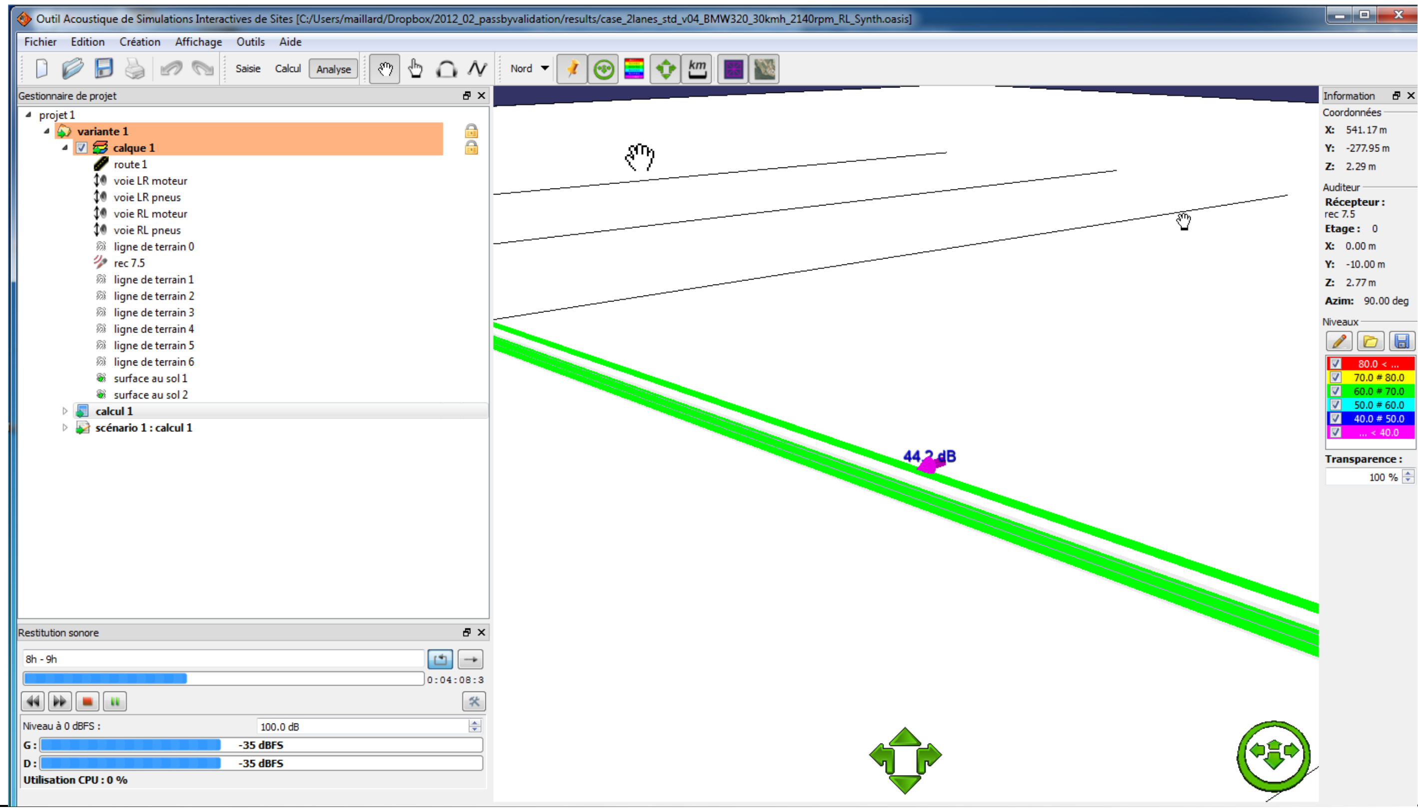
$P(g,v_i)$ probability of driving at gear g for speed v_i

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

Quantitative validation Approach (cont'd)

- ✓ Engine and rolling noise dataset from CPX recording on same road / vehicles
- ✓ Site modeling (approximate terrain data and ground propperties)
- ✓ Auralization
- ✓ Signal analysis (Leq, Lamax, …)
- ✓ Listening tests

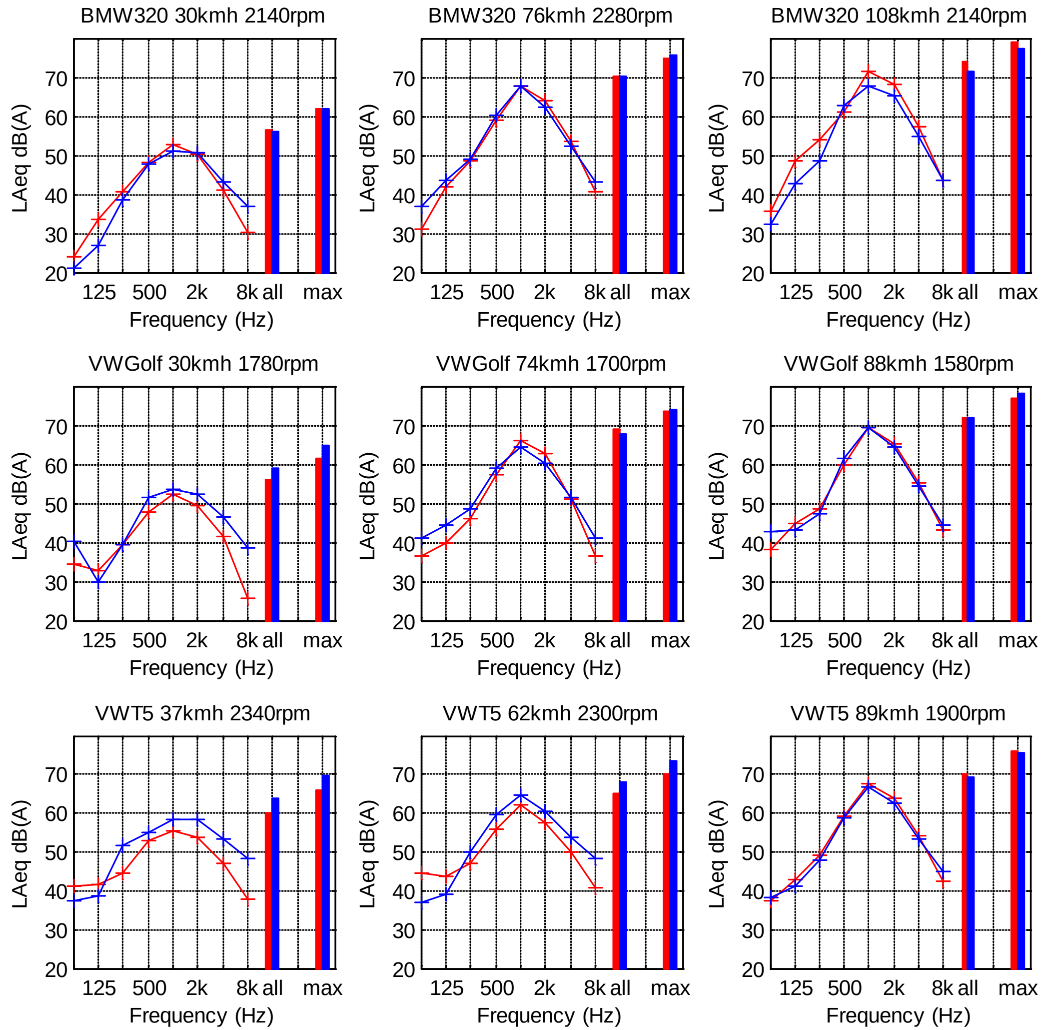


Quantitative validation
Results

BMW 320

Volkswagen Golf

Volkswagen Transporter

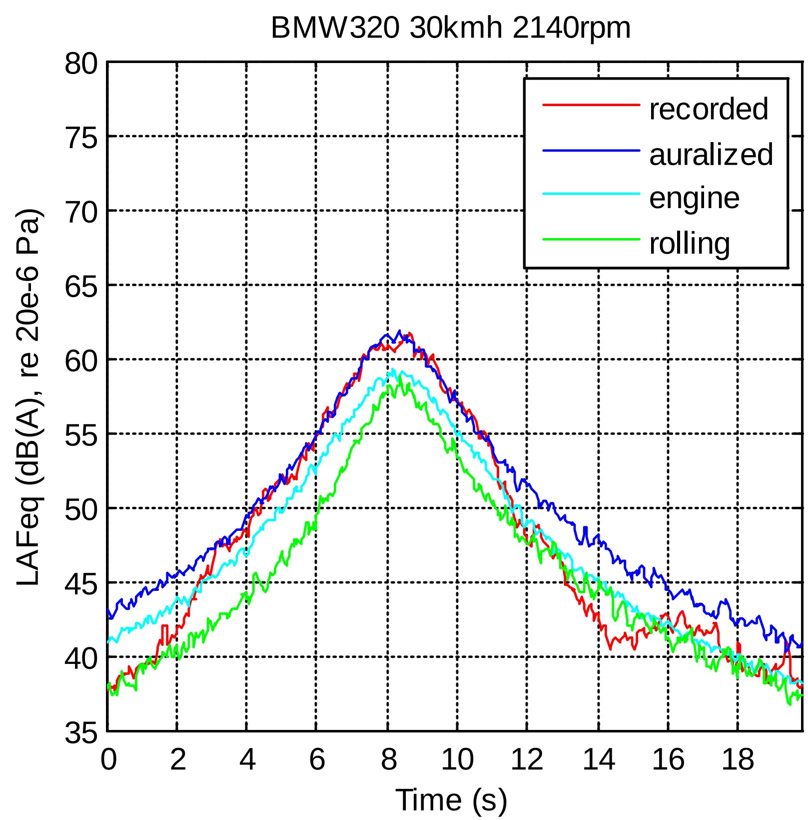


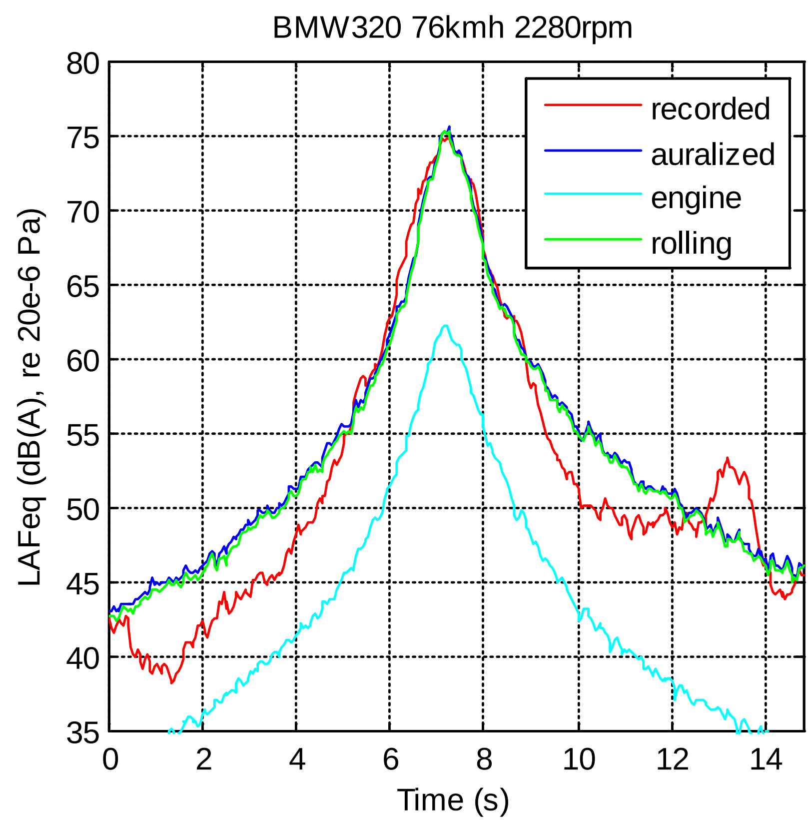
---- recorded

---- auralized

Quantitative validation Results (cont'd)

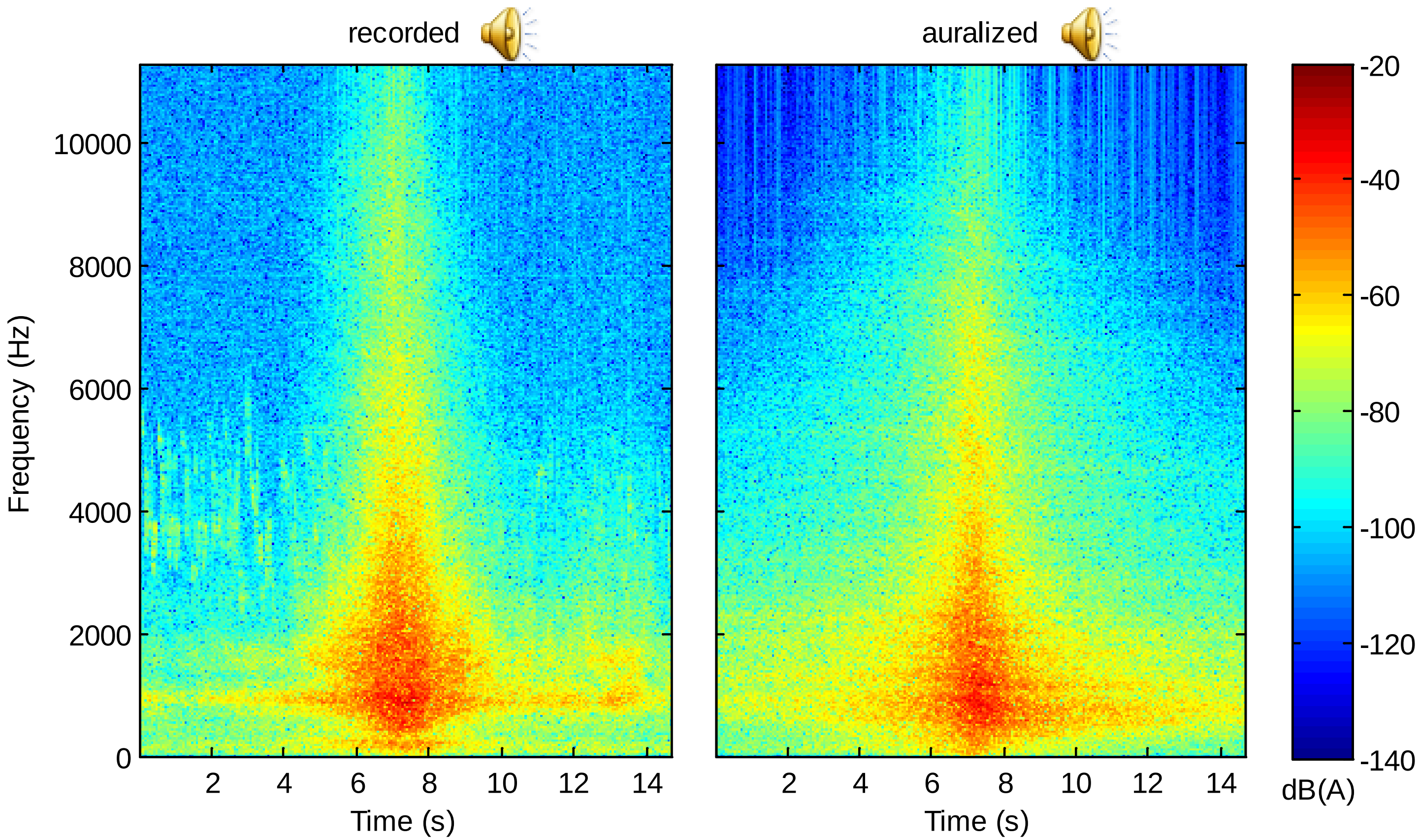
BMW 320 – LAFeq vs Time





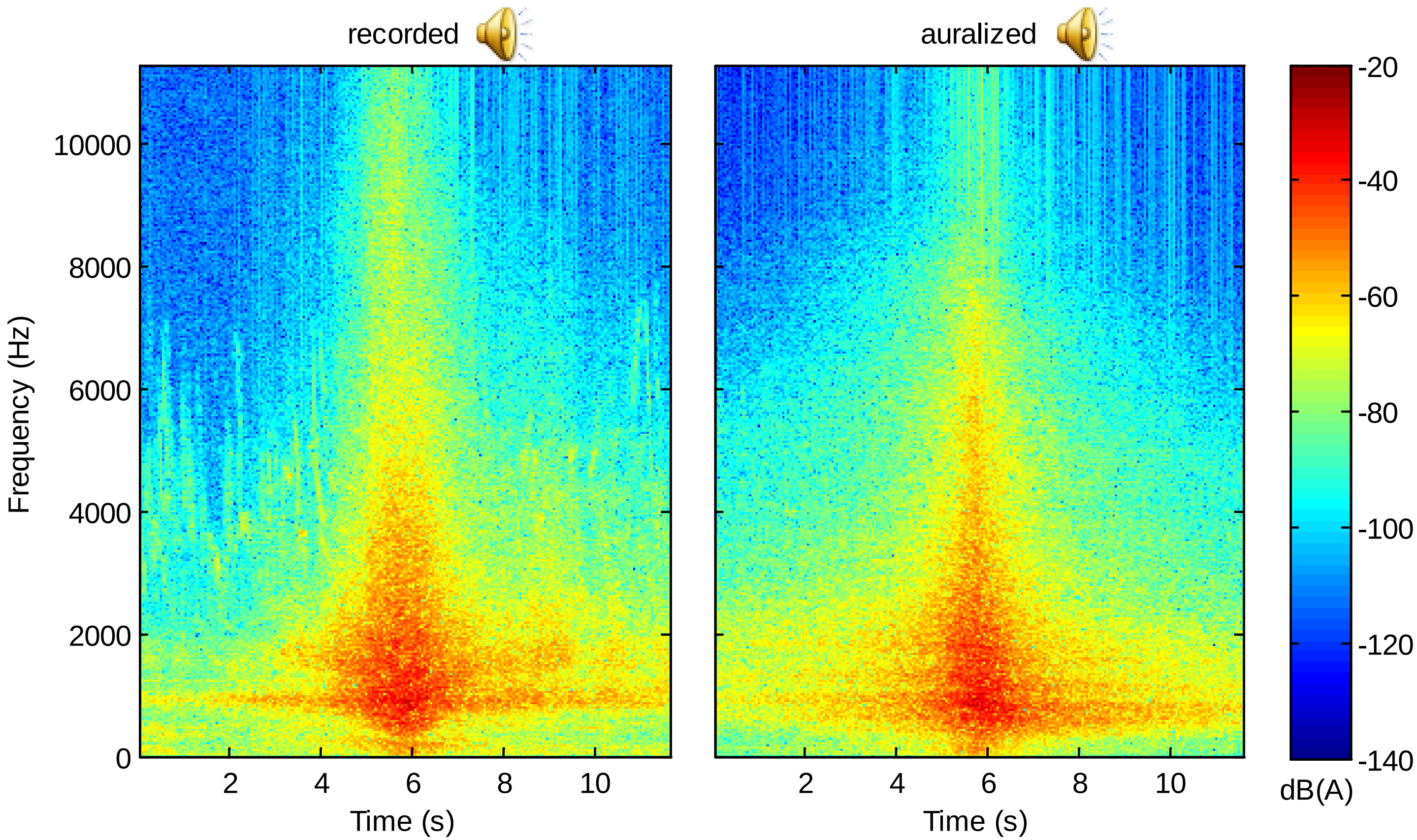
Quantitative validation
Audio samples

BMW 320 - 76 km/h - 2280 rpm



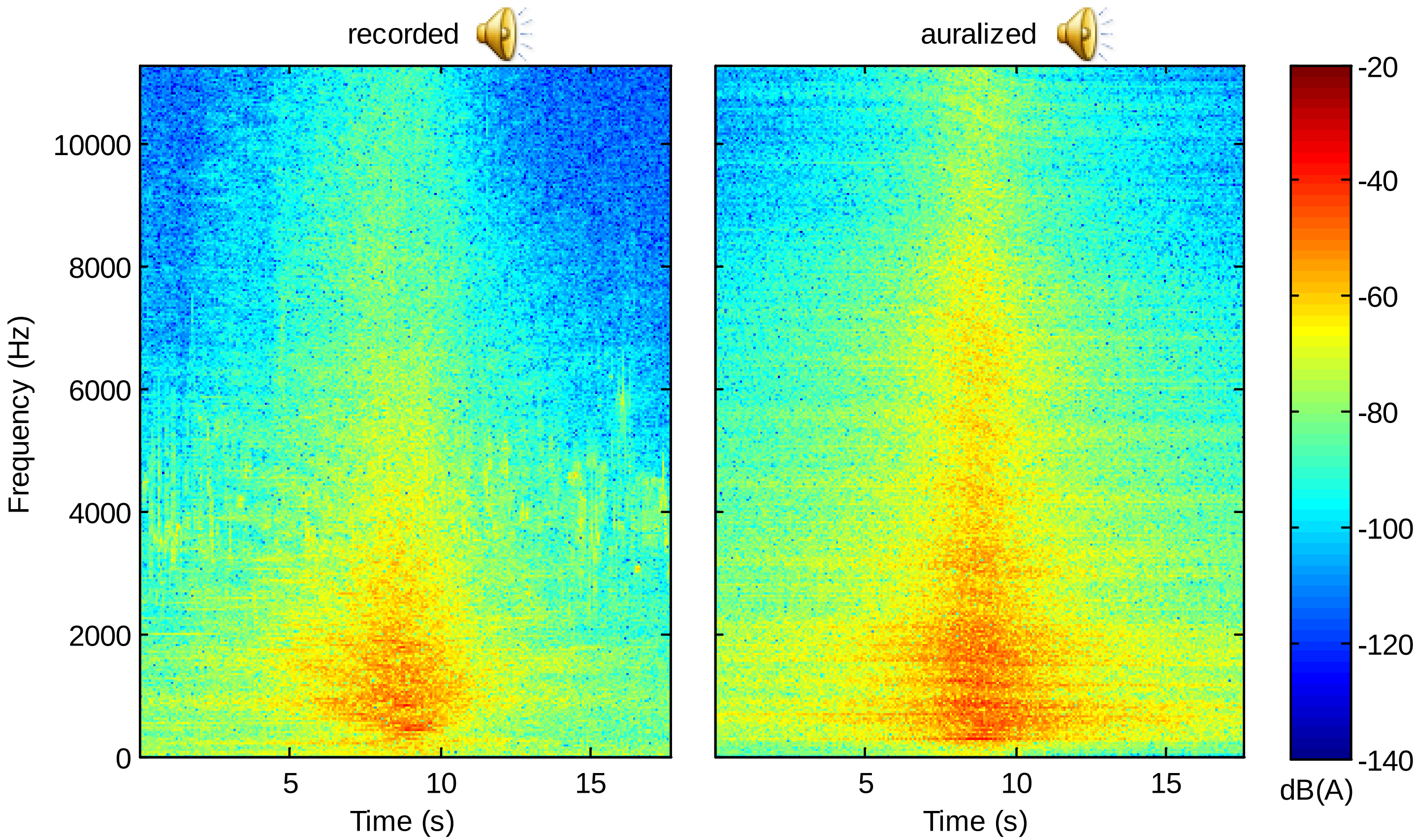
Quantitative validation
Audio samples (cont'd)

Golf - 88 km/h - 1580 rpm



Quantitative validation
Audio samples (cont'd)

Transporter - 37 km/h - 2340 rpm

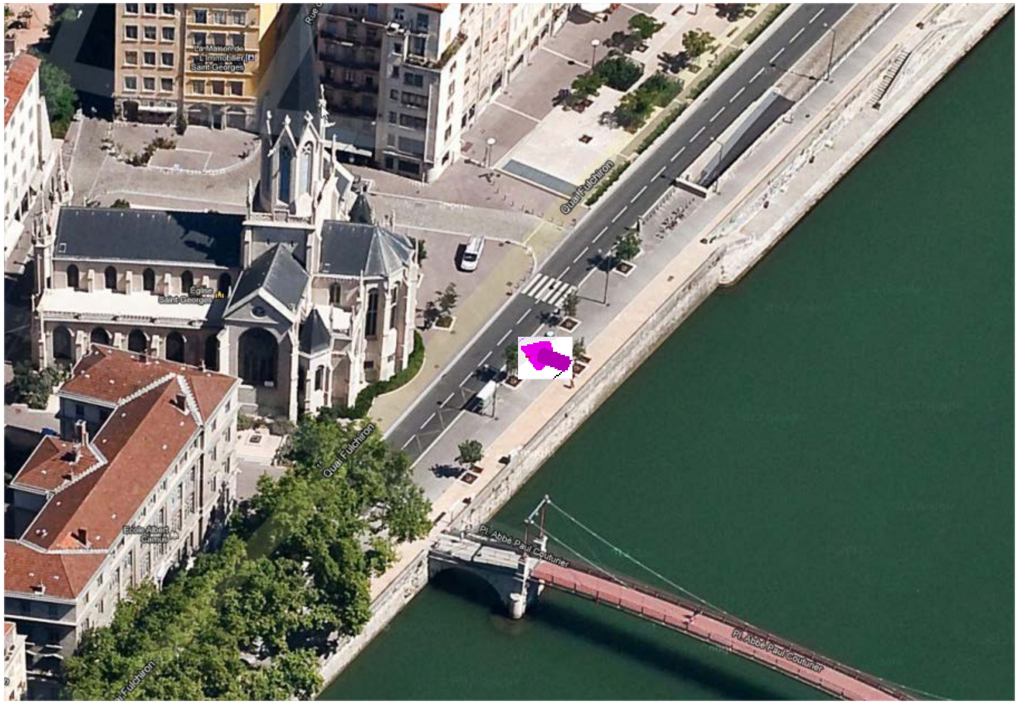


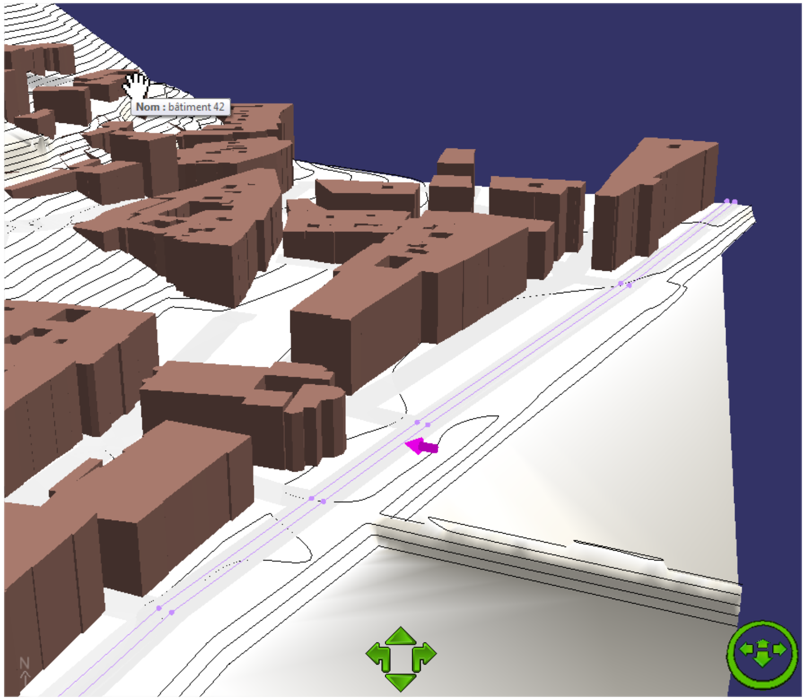
Audio samples
Real traffic in urban site

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

Auralized trafic

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

Acknowledgements

- ✓ 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