Domain-oriented services and resources of Polish Infrastructure for Supporting Computational Science in the European Research Space – PLGrid Plus

Application of PL-Grid platform for modeling of the selected acoustic phenomena

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Presentation outline

- PLGrid Plus project
- Motivation
- Contribution to Acoustics Domain Grid
  - Noise mapping service
  - Hearing service
- Results
PLGRID PLUS PROJECT
PLGrid Plus Project

- Domain-oriented services and resources of Polish Infrastructure for Supporting Computational Science in the European Research Space

- Most important task is preparation of specific computing environments – so called domain grids i.e., solutions, services and extended infrastructure (including software), tailored to the needs of different groups of scientists.

- 13 groups of users:
  - AstroGrid-PL
  - HEPGrid
  - Nanotechnologies
  - Acoustics
  - Life Science
  - Chemistry and Physics
  - Ecology
  - SynchroGrid
  - Energetics
  - Bioinformatics
  - Health
  - Materials
  - Metallurgy.
Domain Grid Acoustics (D1)

- Contribution to Acoustics Domain Grid
  - Tools for sound source and propagation modeling – Noise mapping service
  - Tools for modeling of hearing effects caused by excessive sound level – Hearing service
MOTIVATION
Motivation

- Raising awareness about problem of environmental noise occurrence and its influence on hearing
- Reducing hearing impairments caused by excessive environmental noise
- Noise annoyance
Typical health effects from noise

- Sleep disturbance
- Loss of efficiency of working or learning
- Hypertension
- Increased risk of depression and psychological disorders
- Hearing loss evoked by excessive noise
NOISE MAPPING SERVICE
Noise map

- Noise source description
- Propagation conditions
- Noise indicators: $L_{DEN}$, $L_{NIGHT}$

Numerical procedure

Source model → Propagation model → Noise level at the receiver
Source model

Vehicle model
- Propulsion noise
- Rolling noise

Traffic model
- Number of vehicles per hour
- Road geometry
- Type of traffic flow
- Surface type

\[ L_{W,m,i} = L'_{W,m,i} + 10 \log \left( \frac{Q_m v_0}{1000 Q_0 v_{eq,m}} \right) \]
\[ L_{Eq1h,i,n} = L_{W,i} - A_{div} - A_{atm,i} - A_{refl,i} - A_{sc,i} - A_{E,i} \]

- \( L_{W,i} \) – sound power level of source,
- \( A_{div} \) – the attenuation due to geometrical spreading,
- \( A_{atm,i} \) – the attenuation due to atmospheric absorption,
- \( A_{refl,i} \) – the attenuation due to energy loss during reflection,
- \( A_{sc,i} \) – the attenuation due to scattering,
- \( A_{E,i} \) – excess attenuation due to ground reflections and diffraction effects,
- \( i \) – frequency index.
Noise model

Source

- Basic source properties
  - Databases
  - Measurement methods

Traffic flow

Propagation

- P2P model
- Meteorological conditions
- Geometry
  - Surroundings
  - Buildings

Propagation classes

$L_{den}$
Noise mapping service

- Simulation of acoustic climate in urban area based on data provided by user. Offline mode.
- Dynamically updated map of road noise, based on pre-calculated propagation paths and dynamically changed road traffic data (number of vehicles, speed). Noise maps can be updated fast.
- Estimation of traffic volume based on measurement of noise using reverse model. The outcome is provided in a form of dynamic noise map.
Dynamic noise map

- Concept of calculation of traffic volume based on acoustic climate measurements.
- Estimate traffic flow, on-line access to street traffic data.
- Base map of the area (roads, buildings).
- Sensors location data.
- Noise level at considered points.
- Outcome verification, correction of sensor data.
- Traffic flow data change.
- REVERSE MODEL OF ROAD NOISE.
- Calculation of map for the area.
- Calculation of map for 1-hour traffic data.

**Noise monitoring website for Gdańsk**
Map of noise sensors
Example of measurement sensor
Reverse model

Noise source → Acoustic pressure → Noise monitoring station → $L_{Aeq,T}$ → Reverse function → Traffic flow → Noise prediction model → Immision levels → Dynamic noise map
Dynamic noise map

00:00-00:59
HEARING SERVICE
Today’s methods of hearing impairment risk evaluation are mostly based on the equal energy hypothesis.

The time characteristic of noise is ignored while the main emphasis is put to the equivalent noise level.

The new way of assessment of noise-induced harmful effects on human hearing system.

It is based on some psychoacoustical properties of the human hearing system and, at the same time, on evaluation of the time and frequency characteristics of noise.
Psychoacoustical noise dosimeter

\[ y = D(1-e^{-t/\tau}) \]

\[ y = Ce^{-t/\tau} \]
The results obtained in the laboratory - hearing

TTS [dB]

-2
0
2
4
6
8
10
12
14
16
0 10 20 30 40 50 60 70 80

Measurements
Simulation

Time [mines]
Psychoacoustical noise dosimeter

Input signal -> FFT -> Psychoacoustical model

Transition Function From outer to inner ear -> Basilar membrane response

Asymptotic Threshold Shift modeling -> Exponentially averaged Instantaneous value

Determination of the hearing threshold shift for the given noise signal in real time
Use cases for developed services

- Calculation of the auditory effects induced in hearing system during the exposure. User should deliver the sound recording for considered acoustic and exposure conditions. (Hearing)

- The user define the properties of noise exposure such as sound level (in dB(A)) and time (in minutes) of exposure, the spectrum of noise is calculated based on recorded sound sample. (Hearing)

- During calculation of the noise immission levels, the maximum TTS values for every point are obtained. The calculated sound immission in 1/3 octave bands provides a base for estimate of TTS of hearing using an advanced model. (Noise mapping + Hearing)
SIMULATION OF OUTDOOR CONCERT
A noise-induced temporary threshold shift simulation during outdoor concert at the city square was made.

- Auditory area: about 100×130 meters
- Point sources
  - Energy given in 1/3 octave bands
  - Detailed source directivity
- Noise map and hearing threat map
Noise maps for point sources

Sum: 250 Hz to 10000 Hz

Sound level \( (L_{Aeq})_{8000} \)

Temporary threshold shift \( (TTS_{max})_{8000} \)

\[
\begin{align*}
\text{Sound level} & \quad (L_{Aeq})_{8000} \\
\geq 20.0 & \quad \text{Green} \\
\geq 40.0 & \quad \text{Dark Green} \\
\geq 50.0 & \quad \text{Dark Yellow} \\
\geq 60.0 & \quad \text{Yellow} \\
\geq 70.0 & \quad \text{Orange} \\
\geq 80.0 & \quad \text{Red} \\
\geq 90.0 & \quad \text{Dark Red} \\
\geq 100.0 & \quad \text{Purple} \\
\geq 110.0 & \quad \text{Blue} \\
\geq 120.0 & \quad \text{Dark Blue} \\
\end{align*}
\]

\[
\begin{align*}
\text{Temporary threshold shift} & \quad (TTS_{max})_{8000} \\
\geq 1.0 & \quad \text{Light Green} \\
\geq 5.0 & \quad \text{Green} \\
\geq 10.0 & \quad \text{Dark Green} \\
\geq 15.0 & \quad \text{Dark Yellow} \\
\geq 20.0 & \quad \text{Yellow} \\
\geq 25.0 & \quad \text{Orange} \\
\geq 30.0 & \quad \text{Red} \\
\geq 35.0 & \quad \text{Dark Red} \\
\geq 40.0 & \quad \text{Purple} \\
\geq 50.0 & \quad \text{Blue} \\
\geq 60.0 & \quad \text{Dark Blue} \\
\geq 75.0 & \quad \text{Black} \\
\end{align*}
\]
Noise maps for point sources

$L_{Aeq}$ and $TTS_{max}$, variable source level

90 dB
The concept and the results of the dynamic noise mapping were introduced.

The analysis of auditory effects caused by the outdoor concert was presented.

The results were obtained by means of supercomputing PL-Grid Infrastructure and developed algorithms of outdoor sound propagation and psychoacoustical noise dosimeter.

Provided services may help to predict the annoyance of the outdoor acoustic events or to protect hearing of the audience.

Application of developed services in education.
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