Content of lectures

Basics of sound propagation (Dick Botteldooren)

To assure that all participants have the same background knowledge, this lecture will briefly review the basic physics of sound propagation. It will start by re-introducing basic descriptors such as decibels and octave band spectrum. Source sound power, sound intensity and sound pressure will be discussed. The wave equation will be introduced both in time and frequency domain and some fundamental solutions such as plane waves, spherical waves, far-field solutions will be derived. This lecture will also put in perspective the different approaches used to solve sound propagation problems that will be addressed in detail in the other lectures of this winter school.

Sound interaction with soils (Jens Forssen)

- Introduction to plane wave reflection on flat surface with infinite and finite impedance
- Ground effect on sound propagation
  - Definition of specific acoustic impedance
  - Local and extended reaction
  - Impedance models
  - Plane wave reflection factor
  - Spherical wave reflection factor (and approximate solutions)
  - Sound pressure level relative to free field
- Ground effect and refraction – reflection factor changes with angle
- Ground effect and barriers – briefly (4 ray model)

Meteorological effects on sound propagation (Timothy Van Renterghem)

Sound propagation outdoors is strongly influenced by meteorological conditions. In this talk, the effect of wind, air temperature and relative humidity is discussed in detail, both from a physical point of view, and how this is included in various modeling approaches. It is further shown that meteorological effects should be considered when designing noise reducing devices like a noise wall, a berm or tree belts.

Urban sound propagation (Timothy Van Renterghem)

This lecture specifically addresses sound propagation issues of concern in the built-up environment, like multiple reflections in urban canyons leading to street amplification, canyon-to-canyon propagation, the importance of diffuse sound fields in urban streets, the topic of highly shielded urban zones and the relevance of roof shape. The physical aspects of the urban sound propagation problem will be discussed, and complemented with results from detailed numerical calculations.

Basic concepts in GIS (Luc Dekoninck)

This course will guide you through a few basic concepts of geographic information systems. First two basic types of geographic data, vector and rasters, are introduced. Points, polylines and polygons will feed the acousticians with dwellings, emission and immission points, line infrastructure, buildings and other spatial input.

The world of GIS is in an avalanche of innovations. We briefly introduce the common - but old style data type - ‘shapefile’ and demonstrate the more modern approach of spatial databases. The available GIS software (commercial and open source) is only touched. Examples are demonstrated in the open source software QGis. Some basic spatial operations are shown both on shapefiles and in spatial databases.

A lot of possibilities exist to automate spatial operations. Many of them will be available in noise mapping software, but some data cleaning might be necessary to reduce the complexity of the noise propagation calculations. A road network is converted in point sources, a building layer is generalized, and an immission grid is generated. A sample of a noise calculation map is interpolated to a raster and contour plotting is illustrated.

Linking road traffic modelling and noise (Bert Decoensel)

This course presents an overview of traffic model based techniques for road traffic noise prediction. The components of a typical traffic noise prediction model will be briefly discussed. Subsequently, the course will focus on two main components, the traffic model and the vehicle noise emission model. An overview of various transportation planning, traffic flow and noise emission modelling approaches will be given, with emphasis on the advantages and drawbacks of each approach for traffic noise prediction. Spatio-temporal resolution, input data needs and model calibration will be discussed. The course will be illustrated with practical examples using Paramics and Aimsun.

ISO 9613-2 and noise mapping software (Erwin Hartog van Banda)

The ISO 9613 method is the most used propagation method for environmental Noise prediction worldwide. The method itself and aspects of modelling environmental noise in general will be discussed. The general setup for prediction environmental noise including the difference between a source model and a propagation model will be shown. An overview of empirical, theoretical and numerical methods will be given. Also uncertainties when implementing environmental noise prediction methods in software will be addressed.

Hands-on workshop noise mapping with Predictor software (Erwin Hartog van Banda)

This workshop consists of hands-on exercises with the Predictor software. After a short introduction of the software the participants will create and calculate an industrial situation and an road traffic situation. After the hands-on session a final presentation is given regarding a case study for mapping a large area. [*In the break before the workshop the participants can install the software on their own laptop*]

Noise mapping in practice and the Environmental Noise Directive (Beate Altreuther)

1. The European Environmental Noise Directive (END):
    1.1. underlying principles
    1.2. method “strategic noise map”
    1.3. noise sources to be considered
    1.4. harmonized noise indicators L_{den} and L_{night}
    1.5. Further use of “strategic noise maps”: calculation of number of people annoyed or sleep disturbed by noise; informing the public; addressing local noise issues; basis for the development of “noise action plans”.
2. Strategic noise mapping in practice
    2.1. Minimum requirements for “strategic noise maps” given in the END
    2.2. Setting up “strategic noise map”: necessary level of detail
    2.3. Different types of evaluation: level grid maps, isophone lines, difference maps
    2.4. Noise action plans: implementation of noise reducing measures

---

Hands-on workshop noise quantities and analysing measurements (Dick Botteldooren, Bert De Coensel)

During this workshop the students will learn how to calculate aggregated quantities from raw and detailed measurements and to process spectral data. The workshop will be based on real data from two extended measurement campaigns: mobile measurements in a park close to a highway and measurements in the front and the back of a building close to a road. Theory on using GIS and noise propagation will be integrated in the exercises.

Geometrical acoustics (Jian Kang)

This talk will present computer simulation techniques based on geometrical acoustics (i.e. energy-based models), including (1) the image source method, which treats a flat surface as a mirror and creates an image source; (2) ray tracing, where a sound ray can be regarded as a small portion of a spherical wave with vanishing aperture, which originates from a certain point; (3) various forms of beam tracing, where beams are rays with a non-vanishing cross-section; (4) the radiosity method, which is useful for considering diffusely reflecting boundaries; and (5) combination of those methods, such as combined ray-tracing and radiosity model (CRR). This talk will also give examples of using those techniques for considering urban environments.

Time-domain modelling (Timothy Van Renterghem, Maarten Hornikx, Kurt Heutschi)

This lecture introduces some key aspects of time-domain modelling, and 3 common time-domain techniques that have been applied to outdoor and urban sound propagation cases are discussed in detail.

The finite-difference time-domain method FDTD (Timothy Van Renterghem)

Common possibilities for temporal and spatial discretisation are explained, starting form the sound propagation equations in absence of flow and in a homogeneous medium. Their impact on numerical efficiency, numerical accuracy and numerical stability are discussed in detail. In a next step, a moving and inhomogeneous sound propagation medium is introduced, and the impact on these numerical aspects will be discussed. The implementation of finite and infinite absorbing boundary conditions in the FDTD context is treated in a next step.

The pseudo-spectral time-domain method PSTD (Maarten Hornikx)

- Aspects of time integration with the Runge-Kutta method
- Solving spatial derivatives, including boundary conditions, by the Fourier pseudospectral method
- Developments in PSTD: multi-domain and curvilinear PSTD method
- Advantages and disadvantages of the method
- Applications with PSTD

Numerical Simulations with the Transmission Line Matrix Method TLM (Kurt Heutschi)

The part starts with a discussion of the underlying physical model of TLM simulations. The propagation of sound is represented by plane waves running along a grid of small tubes. The equations to describe transmission and reflection at a cross sectional change of a tube are then derived and applied to the TLM grid structure to come up with an updating scheme for unbounded situations. It is then demonstrated how boundaries and non-homogeneous media can be taken into account. Finally, practical examples of applications of time domain simulations are presented.

Frequency domain modelling (Dick Botteldooren)

For outdoor sound propagation problems encountered in urban noise planning it might still be efficient to solve the wave equations in frequency domain although one is generally interested in a broad frequency range response, provided that the numerical technique on itself is extremely efficient. Two techniques will be briefly touched upon in this lecture: the boundary element method and the parabolic equation approach. The former has the advantage that the number of unknowns is drastically reduced, the latter assumes propagation in a known and well defined direction of interest. After introduction of the techniques, their application area will be discussed and they will be compared to the other techniques discussed during this winter school.

Noise reduction by natural means (Jens Forssen)

The lecture presents a brief overview of a recent EC project about innovative methods for road and rail traffic noise reduction between source and receiver. The methods include using new barrier designs, planting of trees, treatments of ground and road surfaces and greening of building facades and roofs using natural materials, like vegetation, soil and other substrates in combination with recycled materials and artificial elements. The abatements are assessed in terms of numerically predicted sound level reductions, perceptual effects and cost–benefit analysis.

Urban quiet sides (Maarten Hornikx)

The lecture presents an overview of the EC Life+ research project QSIDE, specifically addressing the topic of quiet sides and quiet areas in the urban environment. Various aspects will be considered ranging from the development of an engineering model to improve predictions at (strongly) shielded building facades (in noise maps), the beneficial effect of quiet sides for noise annoyance and sleep disturbance, and how city noise policy implements and uses the quiet side concept.

Noise reduction during propagation : hands-on workshop numerical modelling (Timothy Van Renterghem, Maarten Hornikx, Kurt Heutschi)

The students work on sound propagation in time-domain in an urban environment using a PSTD implementation that will be made available. Two configurations are considered:

a) vertical cross-section of an urban configuration, with main trafficked street, and parallel traffic-less street.

b) horizontal cross-section of an urban configuration, with a main street (with noise source), cross-streets and a parallel traffic-less street.

For both configurations, impulse responses are computed. In a), level differences between various receiver positions are investigated, in b), the most favorable location of mounting a limited amount of façade absorption is investigated.

Lecturers

Beate Altreuther (Dipl.-Phys) obtained her Physics diploma at Stuttgart University. Since 1989, she works at Müller-BBM GmbH as a consultant for sound and vibration with the main focus on traffic noise reduction. Since 2001, she worked for several national and international research projects on the reduction of tire-road noise (e.g. Quiet Road Traffic (Germany), ITARI (EU 6th framework) and HOSANNA (EU 7th framework)) as well as in several national projects dealing with low noise concrete roads.

Juergen Bauer is an Architect and lecturer at Waterford Institute of Technology, Ireland. He studied at Braunschweig Technical University, Germany, and the Federal Institute of Technology in Zurich, Switzerland, from 1986 to 1993. He practised as an Architect in Braunschweig, Munich and Berlin. Since 2005, he has worked as a lecturer in the Department of Architecture in Waterford I.T. Juergen's field of research is "sound in architecture and urban design" i.e. how both the soundscape approach and the design process can contribute to one another.

Dick Botteldooren, MSc in engineering (Ghent University), PhD (Ghent University), is a full professor in acoustics and the head of the acoustics research group at Ghent University. His current research interests include urban sound propagation, smart sound monitoring, soundscape analysis and design, and interaction of environmental sound with humans. The latter includes hearing and its protection, perception, cognition, and annoyance. This work has been reported in over 100 peer reviewed journal publications. Dick Botteldooren is the president of the Belgian Acoustical Association, a fellow of the Acoustical Society of America, a member of IEEE and the Editor-in-Chief of Acta Acustica united with Acustica.

Bert De Coensel is a part-time assistant professor at the Department of Information Technology of Ghent University, a postdoctoral fellow of the Research Foundation-Flanders and an adjunct lecturer at the Griffith School of Environment, Brisbane. His main fields of interest are urban acoustic design, intelligent traffic management and its influence on the urban soundscape, and computational models of human auditory perception, including auditory scene analysis. He is a member of the Belgian Acoustical Society, the Acoustical Society of America, the Audio Engineering Society and IEEE. He is expert member of ISO working group TC43/SC1/WG54 on perceptual assessment of soundscape quality.

Luc Dekoninck, Master in Physics, is a certified expert for environmental noise for the Flemish government. He is specialized in long-term environmental noise measurements and analysis. He has been calculating noise maps for over ten years for different sources, mainly road traffic and railway. The map sizes range from city development simulations through alpine valleys up to the complete Flemish region. He mastered many techniques for handling the geographic data issues that emerge when building noise maps. He is currently working on spatial analysis and modeling of traffic livability, annoyance and the time-activity pattern related to personal exposure to air pollution.

Jens Forssén is an Associate Professor at the Division of Applied Acoustics, at Chalmers University of Technology. His area of research is outdoor sound propagation. The research deals mainly with physical modelling and numerical methods, but measurements constitute also an integral part. Among the research topics are: general outdoor acoustics, i.e. effects of meteorology, terrain and ground conditions, sound propagation in urban environments, sound propagation to inner yards, road and rail traffic noise, wind turbine noise, noise barriers, performance of noise barriers in conditions of atmospheric turbulence, statistical parameters of urban acoustics and auralization of road vehicles and urban acoustics.

Erwin Hartog Van Banda is employed as Senior consultant of the Software and IT division at the Dutch company DGMR Consulting Engineers. DGMR employs 160 people, divided over 9 divisions. He is responsible for the development, marketing and sales of the international DGMR software. After studying in electronics and acoustics, he started working at DGMR in 1981 as an acoustic consultant. He was involved in measuring, modeling and management of noise from large industrial sites like harbors, ship yards and petro-chemical industries. After completing his post graduate study for software engineering he ventured over to the implementation of noise calculation methods and noise management methods in commercial software. DGMR has been involved in the development of several noise management systems for the Dutch authorities like Silence (national highway network) and I2 (industry in the Rotterdam harbor area). Outside of Holland, DGMR is also known for its acoustic-theoretical and acoustic-software related work within the European Harmonoise, Imagine and CNOSSOS projects.

Kurt Heutschi received his master's degree (MS) in electrical engineering from the Swiss Federal Institute of Technology Zurich (ETH) in 1986. He completed his dissertation about sound fields in urban environments at the Information and Signal Processing Laboratory of ETH in 1993. Since then he is working at Empa, the Swiss Federal Laboratories for Materials Science and Research in the Acoustics / Noise Control Department with core areas road traffic noise, numerical models for sound field calculations and sound propagation over large distances. Since 1995 he is teaching Acoustics at ETH as an assistant lecturer.

Maarten Hornikx is assistant professor in the chair of Building Acoustics (TU/e). He holds a PhD in Applied Acoustics from Chalmers University of Technology (2009), he has worked as a post-doctoral research fellow at KU Leuven in the aeroacoustics research group and as a senior researcher at Chalmers University of Technology. Hornikx' research area is numerical modeling of sound propagation in the built environment and his research interests are: efficient wave-based modeling approaches, modeling of sound propagation in (semi)-enclosed spaces, the influence of vegetation on sound propagation, influence of meteorological effects on sound propagation and auralization for human echolocation.

Jian Kang, BEng MSc (Tsinghua University, Beijing), PhD (University of Cambridge), has been Professor of Acoustics at the University of Sheffield, UK, since 2003. Previously he worked at the University of Cambridge and the Fraunhofer Institute of Building Physics in Germany (Humboldt Fellow). He is distinguished by his work in environmental acoustics, evidenced by 60+ prestigious engineering-consultancy projects, 60+ funded research projects, and 600+ publications. His work on acoustic theories, design guidance and products has brought improvements to the noise control in underground stations/tunnels and soundscape design in urban areas. He is a Fellow of the UK Institute of Acoustics (IOA), a Fellow of the Acoustical Society of America (ASA), a UK chartered Engineer, and the Editor in Environmental Noise for Acta Acustica united with Acustica (European Journal of Acoustics). He chairs the Technical Committee for Noise of the European Acoustics Association; the WUN (Worldwide Universities Network) Environmental Acoustics Network; and

EU COST Action on Soundscape of European Cities and Landscapes. He was awarded John Connell Award 2011, and UK IOA Tyndall Medal 2008.

Timothy Van Renterghem, Msc in bio-engineering (Ghent University), obtained his Phd (Ghent University) in 2003 on the topic of “time-domain modelling in outdoor sound propagation”. He is currently appointed as part-time professor at Ghent University, Belgium, in the field of environmental sound. He teaches courses related to environmental noise, acoustical instrumentation and computational methods. He is author/co-author of near 40 peer-reviewed international journal publications and 70 conference contributions. He is Associate Editor of Acta Acustica united with Acustica, the journal of the European Acoustical Association EAA, in the field of “Atmospheric sound”. He is a member of the Belgian Acoustical Society, European Acoustical Association and the Acoustical Society of America. His main research interests are urban sound propagation, detailed numerical modelling in outdoor sound propagation including meteorological effects, and how natural means can be used to mitigate noise problems.