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GIS: AN ESSENTIAL TOOL FOR NOISE MAPPING

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ABSTRACT
A noise impact assessment depends principally on the calculation of noise maps, using a set of standard calculation to define the contribution of different sources. A model for noise mapping constitutes an original software product incorporating a proper user’s interface, calculating module and data bases that provide the modelling process with source data. A few commercial software packages such Cadna-A, SoundPlan, IMMI and Predictor Lima are available for noise calculations. Although the above-mentioned noise software is fully-featured it also presents some limits in the reiteration of tasks and in post-processing the results. Recently many challenges are related to the integration of geographic information systems (GISs) with physics models in different disciplines also in the acoustic field. GIS is a technology for handling geographic data in digital form. It allows the pre-processing of data into a form suitable for analysis, it supports the spatial analysis and the postprocessing of results. This work is an overview in the existing techniques to organize the input data and automate tasks, the main advantages in linking GIS and noise software are also described.
KEYWORDS: Noise mapping, acoustic software, GIS, Interoperability

INTRODUCTION

The Environmental noise Directive 2002/49/EC states that the environmental noise is “any unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, and air traffic and from site of industrial activity”. [1]

The World Health Organization (WHO) identifies noise as the second most significant environmental cause of ill health. [2]

Environmental management relies on scientific evidence to make decisions using key performance indicators to demonstrate achievement. The use of acoustic models allows to manage the environmental configuration by the identification of significant noise sources, the characterization of the sources (generation models), the study of the spread between source and receiver (propagation models). Acoustics models are used to determine the contribution of individual sound sources in a define area under investigation, to forecast noise in the environment at design stage for a new settlement, to determine or compare the effectiveness of noise mitigation solutions. [3]

Noise mapping has become an essential requirement, it’s a complex topic and it requires the processing of a huge amount of data in input/output and it’s not always possible to complete all the required tasks using only the acoustics software. Moreover, the acoustics software is not very flexible and manual adjustments are often required to complete simple tasks which if automated can reduce the time and the cost in data processing.

GIS and acoustics software integration makes easier the formatting and collection of noise input data and the postprocessing of the results.

The development of GIS is based on common agreed standards by developers of products, interoperable qualities allows the interconnection of different platform and software modules. The data base format is topologically indexed vector in the standard ‘shape’ format. Cadna-A, SoundPlan, IMMI and Predictor Lima software integrate well with GIS, they allow to import and export data in ’shape’ format. The aim of this study was to have an overview of the main steps to develop an acoustic model using GIS to organize the input data and to create simple models and script in GIS to speed up daily data processing tasks in Cadna-A software modelling.

ACOUSTIC SOFTWARE

Cadna-A, IMMI, Soundplan and Predictor Lima are ray-tracing software. What is a ray-tracing software and how it works?

The perceivable wavelengths of light and sound differ by many orders of magnitude. Visible light consists of wavelengths in hundreds of nanometres, which is thousands to millions of times smaller than the size of the objects we deal with usually, lying in range of millimetres to meters. The wave propagation can be safely reduced to the abstraction of infinitely thin rays propagating in straight lines that undergo local interactions with object geometry upon intersection (geometric approximation) and has served quite well for simulating light transport.

Ray-tracing works in 'geometrical optics' limit. From the acoustic side this means that the rays are considered carriers of patches of acoustic energy travelling along the rays with the speed of sound and after each reflection the energy is reduced according to the absorption properties of the surfaces. [4]

Numerical methods are based on analytical formulas that describe the physical phenomena related to the acoustic propagation starting from source sound power data.

Source type (point, line, areas) defines the acoustic properties of any source in terms of source height from the ground, sound power, and spatial distribution of the sound radiation (directivity). The emission and propagation models are derived from national standards. EU proposed harmonized methods such as Harmonoise, or more recently the CNOSSOS-EU model ('Common Noise Assessment Methods in Europe'). [5]

GIS SOFTWARE

One of the key characteristics of GIS is that every database is georeferenced (located in space by the coordinate referencing system (CRS). The Universal Transverse Mercator (UTM) coordinate system id the most frequently CRS used in GIS.

GIS manages two categories of data required for noise mapping:

- Geometric data such as points (nodes), polylines (arcs) and polygons (area), these objects are the representation of geographic features positioned in the real world; and
- Attribute data which defines the properties of the objects.

The most widely-used GIS software is ArcGIS Desktop developed by ESRI. In ArcGIS, 'scripting' can be used for data management and manipulating maps.

A scripting language is a programming language used to write script. Scripts are sequence of instructions that can be run to execute one or more tasks. Basically, scripts allow to discover data and manipulate software to automate tasks.

Programming involves the use of more complex code while scripts are typed in as distributed in plain text. There are several scripting languages such as Python, JScript and Perl but between these Python is the most utilized by GIS users also for the fact that Python is 'object-oriented' and in GIS map documents and feature classes are objects [6]

Python is an open-source language it means the source code is shared with the public.

A script allows to insert conditional logic to handle cases which require the use of different tools. There are two sets of tools for using GIS in Python: the first is by using python scripts to control ArcGIS and the second is using native Python tools.

Plenty of GIS open-sources platforms are also available on the market and they allow to cut the license costs. QGIS is the most used, the application supports shapefiles, geodatabases and other formats. QGIS platform also offers several plugins developed from QGIS users. A plugin is a software component that adds a specific feature to an existing computer program. Pyqgis scripts can be run via the Python Console in QGIS. [7]

REQUIRED DATA FOR NOISE MODELLING

Noise mapping requires a big amount of data concerning the investigated area, based on third-party data or models.

Referring to a road scheme the following information are required to develop the model in Cadna-A:

- Digital Terrain Model (DTM);
- Buildings/receptors (heights, addresses); and
- Roads (network comprehensive of bridges tunnels and viaducts, traffic flows, speed limits, signage)

The following paragraphs describe some technique that can be used in GIS to organize the input data.

DTM (DIGITAL TERRAIN MODEL)

A DEM is a digital representation of the earth surface. There are usually two types of DEMs, a DSM (Digital Surface model) that includes everything captured in the elevation data and a DTM (Digital Terrain Model), which is a representation of a ground surface where vegetation and buildings are not included.

The European Commission Working Group Assessment of Exposure to Noise (WG-AEN) recommends that the DTM adjacent to the noise sources needs an accuracy of 1m. When a comprehensive file for DTM is used for large areas the time of calculation critically increases. Ground model/topography can be provided in various formats ranging from CSV excel files with height point data associated with x, y coordinates (vector points) to a raster dataset.

Many raster datasets are in the form of scanned images (aerial photography) or satellite images. Basically, a raster dataset is a grid of pixels (picture elements) that have a specific assigned value. There are several options for the representation of the pixels. Conceptually a picture consists in a two-dimensional arrow of pixels imposed by the elaboration software. The way these pixels are represented in binary depends on the type of picture and the conventions used, ASCII code (American Standard Code for Information Interchange) is a convention for the representation of text characters using binary values.

In UK the Department for Environment, Food and Rural Affairs (Defra) provides an on-line Data Services Platform to download LIDAR (Light Detection and Ranging) Data. The Data Services Platform is managed by the Environmental Agency.

LIDAR is a powerful technique that uses optical remote sensing technology based on laser pulses. This technology gives a mapping accuracy of 10–15 cm in elevation. The data can be download with 0.5 m, 1.0 m and 2 m resolution and are provided in ASCII format.

Cadna-A allows to import directly the survey data as ‘points’ using the ASCII grid format, it can also carry out a simplification of the grid points, this process reduces significantly the number of height points in the model. However, to speed up the calculation is more convenient to import the data in Cadna-A as ‘contour line’, the contour represents a continuous elevation, this conversion unfortunately cannot be done in the software.

GIS allows to make this conversion (from vector or raster dataset) in an easy way using vector analysis or raster analysis. In Arc MAP contours lines can be created with different surface interpolation methods this operation requires the ‘Spatial Analyst’ or ‘3D Analyst’ license.

QGIS has good terrain processing capabilities built-in too.

A simple script in GIS also allows to establish ground absorption from land usage maps using a twofold distinction between hard and soft ground.

BUILDING AND NOISE RECEPTORS

Buildings are part of the DSM, land uses, addresses and buildings heights are crucial information to define the noise receptors in any noise assessment. Some land uses are more sensitive to noise than others, Ordinance Survey (OS), that is the national mapping agency for Great Britain, provides Master maps, including various themes such building, roads and rail routes, and Address-Points containing information about the building use (residential, health, educational, religious, commercial, industrial etc.) and addresses.

Master map and Address-Point can be easily combined in ArcGIS and QGIS. Each building (polygon) is identified with a unique numerical ID and address point is used to populate the details on each 'polygon' of master map. This allows to import the buildings in Cadna-A with all the required information.

The building footprints can be extracted from the Ordnance Survey Mastermap Topography Layer (OSMM). These data can also be extrapolated from LIDAR data. The procedure consists in subtract the LIDAR DTM from the LIDAR DSM data and apply a simple statistic tool in ArcMap or QGIS.

The following step is to generate noise receptors associated to the buildings. In Cadna there are few methods that can be followed, the more common is to utilize the 'Building Evaluation' function. This function allows to generate noise receptors around the buildings at define distances and at different heights. 'Building evaluation' is a useful kit for small areas but for bigger ones it increases considerably the time of calculations. Sometimes also only a group of receptors facing a specific road need to be considered, or just the façade that is the more exposed to noise. In Cadna there is the possibility to exclude a specific façade from the calculations, but it needs to be done manually for each building. In all this cases GIS can be a valid solution to generate noise receptors point and simplify the calculations. Several techniques can be used for the scope. The most common is to calculate the minimum distances between the vertex of the buildings and the roads. In ArcGIS 'Spatial Analyst' tool need to be used, in QGIS there is the plugin 'find the distance from a road' unfortunately this application can be used with one road per time, but a Python script can be written to extend the numbers of road in the study.

ROADS

Road route as buildings can be derived for the provided Mastermap. The route of the road scheme is usually provided in a series of CAD format files, that need to be 'cleaned' from all the non- physical information. The CAD file can be imported directly in ArcGIS/QGIS, the centreline of the scheme can be extracted and easily exported as a shp file.

Traffic flows are derived from a traffic model and are provided in different formats, the common way is an excel file with an associated road links network (graph).

A graph is a set of vertexes (nodes) connected by edges (links) it is a symbolic representation of a network and of its connectivity, it implies an abstraction of the reality and is simplified as a set of linked nodes. [8]

GIS acts as an intermediate platform to merge the attributes (traffic flow characteristics) of the traffic model with the road network DEM.

Finally, road traffic surfaces based on the identification of homogeneous characteristic can be processable through GIS and easily imported in Cadna-A software.

POST PROCESSING DATA AND VISUALIZATION OF THE RESULTS

Data presentation plays a crucial role as the objectives are made clear with relevant evidences.

In acoustics data visualization is fundamental. The acoustic software allows the visual presentation of the noise effects, but GIS is more flexible in the creation of thematic maps and offers a different approach to present the noise exceedances. [9]

CONCLUSIONS

The overall aim of this study was to collect information on integration between GIS and Acoustics software to save time in organize the data and process them.

The main advantages in the use of GIS are listed below:

- Easy management of huge amount of data;
- Querying and extracting information is quicker due to the creation of database;
- Easy database updating;
- Easy comparison of results of different scenarios; and
- Easy check of data consistency with reduction of mistakes.

Why using script in GIS?

- Manipulate large amounts of data;
- Discover hidden information in data;
- Automate repeatable processes;
- Facilitate testing alternate scenarios; and
- Execute complex or tedious tasks

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