



The 32nd International Congress and Exposition on Noise Control Engineering

Jeju International Convention Center, Seogwipo, Korea,

August 25-28, 2003

[N070] Geometric Post-Processing of GIS Data

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ABSTRACT

GIS data can help generate acoustic models. But this data has typically been collected without any consideration of the demands placed by acoustic calculations. Therefore, in many cases, efficient post-processing of geometry and attribute information turn out to be essential. Various aspects of this process will be addressed, including:

- Bringing data into the proper shape (generating building polygons from single vertices, etc.)
- Terrain models: Contour lines vs. ridge models, reconstructing a given topography to defined planned situations (for example, fitting a new highway in a landscape,)
- Methods of converting 2-D models into 3-D models (interpretation of height attribute information, Laser scan data, use of textual height information, etc.)
- Checking geometric integrity (duplicate objects, source polygons with forward-backward digitising resulting in double emission, etc.)
- Merging geometry of differing quality, and the inheriting of attributes
- Simplification of geometry

When aiming at the exclusive use of commercial GIS tools for data pre-processing limitations of light versions have to be considered.

KEYWORDS: Noise mapping, GIS, calculation, environment, software

INTRODUCTION – WHAT DATA WILL BE PROVIDED IN A GIS SYSTEM?

Increasingly, environmental noise is calculated using complex models in dedicated noise calculation software. Often, using existing data from Geographic Information Systems (GIS) is the only economic approach to create large-scale acoustic models. Such data was often collected over a long period and was not intended as a basis for acoustic calculation. Often it only has 2-D information. Now, 3-D GIS data is collected in a well-structured manner, either from aerial photography or from laser scanning. In addition to pure geometry data, more sophisticated data with attribute information can be delivered. For traffic planning, despite having valuable traffic data, important acoustical details such as road surface are missing. As GIS was originally aimed at drawing functional maps, data may be too detailed for acoustic analysis. In addition, the demands on data accuracy will vary depending on the kind of acoustic analysis done. With this in mind, it is not surprising that GIS data cannot always be used immediately. Tools, either in the GIS or in the noise calculation software, exist to bring data into proper shape and tackle the problems indicated below.

TERRAIN

Digital terrain models (DTMs) are used in noise calculation software to define the terrain heights at objects, and at source or receptor positions. They should also be used as diffraction edges and should prevent the potential reflection of reflectors beneath their base. An efficient noise calculation software relies on an in-built DTM with “relative” height definition, as:

- Model data is often set up by digitising maps and adding 3-D information as attributes
- In most cases, only height information “relative” to terrain will be easily available
- Relative height definition is easy to verify and less vulnerable to diffraction analysis error
- Planned modifications of the model can easily be implemented
- Receptor heights, for instance in a grid, will most likely be defined relative to terrain

To ease use, additional height definitions might also be defined:

- absolute, i.e. height above mean sea level (M.S.L.)
- relative to buildings or edges of neighbouring objects (e.g. embankments or bridges)
- based on a known gradient to a neighbouring terrain object

Simple DTMs work with a chess board like grid of tiles, which can easily cause jumps in diffraction effects at neighbouring receptors. More complex algorithms use interpolation or even extrapolation. However, GIS and noise calculation software do not use the same algorithms when reusing DTM data. The quality of the DTM should be checked by producing contour lines from the input data. This will check the influence of calculation parameters and

show weak spots needing further model input (see Fig. 2). In addition, GIS terrain information can easily create models of hundreds of MB or even GB, thus greatly slowing handling. So it is important to reduce it to that data that is significant for acoustic analysis.

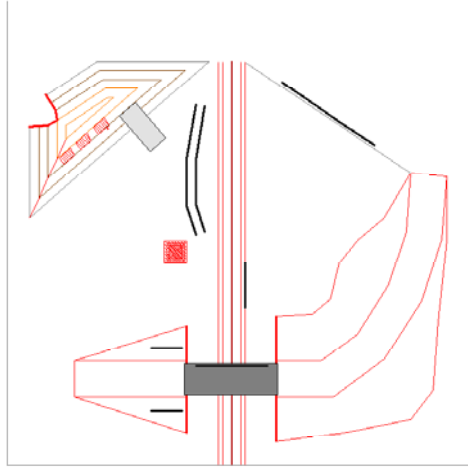


Fig. 1 Various terrain objects and height definitions

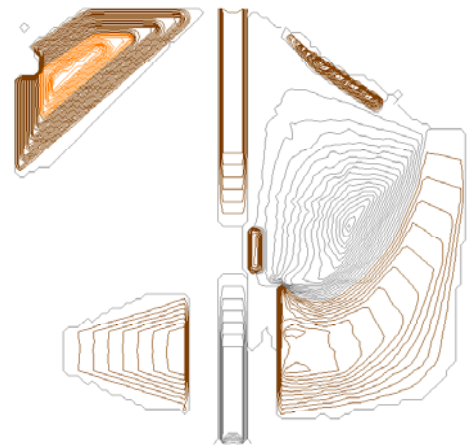


Fig. 2 Contour lines produced for the model in Fig 1 for testing

As basic information to be used in a DTM the GIS model may provide (see Fig 1):

- Point heights
- Contour lines
- Ridges
- Slope edges
- Escarpment edges

Point information needs to be converted into a 3-D terrain surface to be of full use.

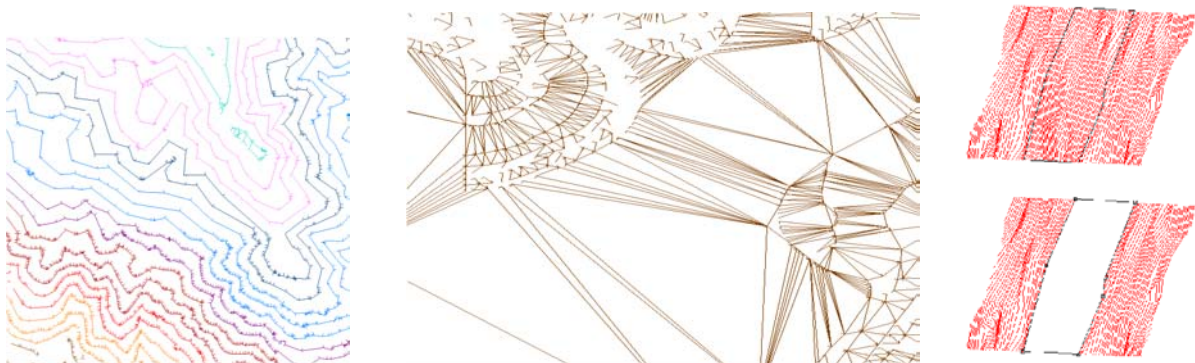


Fig. 3 (a) A terrain contour, shown with segmentation after smoothing. (b) Ridge edges generated between contour lines also carry much redundancy. (c) Clipping of 3-d terrain objects

Contour lines may have been digitised manually or generated from an artificial grid net that tends to meander, thus creating a contour polyline consisting of many vertexes that are far too detailed for our purposes. Sometimes contour lines come in as single segments. This demands concatenation (merging) in order to create suitably simplified polyline objects. Simplification

might be done by just skipping certain height intervals, unless they describe the bottom or top level of the local terrain. More sophisticated smoothing techniques with user-defined accuracy that can be automatically adopted when contour lines are placed close to each other.

Ridge-edge models will in theory describe relevant diffraction edges more directly than contour edges and thus less geometry might be necessary to define the model. However, as it is common practice to generate such ridge edges as triangles from pre-calculated grids, up to 50% of the information may be redundant. Optimisation beyond this is difficult.

For planning purposes, or when updating data, an existing terrain model might have to be reshaped. Clipping of existing geometry is needed and tools should be able to take care of the 3-D data situation. While vertex-related information can be interpolated, care needs to be taken with objects whose height information is defined relative to clipped objects.

HANDLING BUILDINGS AND OTHER POLYGONS

To draw theme-orientated maps, closed polygons are split up into single edge elements to be able to arrange drawing in certain hierarchies. In acoustic modelling, buildings must be closed polygons in order to recognise any receptor position within a building, thus requiring concatenation. This may be hampered by missing line segments that are not generated e.g.:

- a line being beneath a more important line, e.g. building edge beneath border of property
- contours are only digitised if they can clearly be recognised in aerial photography (e.g. edges underneath trees or hidden by higher buildings are missing)

In some 3-D GIS data, building façades are organised as separate façade walls, organised in rectangular sheets. This may cause the z-values at the nodes to jump while concatenating the upper edges into closed polygon objects. Furthermore, such façade surfaces are represented by 3-D triangles. This requires removing all double edges for correct concatenation. Automatic concatenation of such data will provide one polygon object representing the eave and a second one that may be used to describe the terrain.



Fig. 4 Result of automatic concatenation of separated building edges

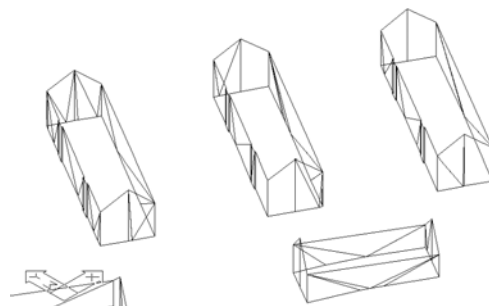


Fig. 5 Examples of 3-D Triangle façade elements that need concatenation

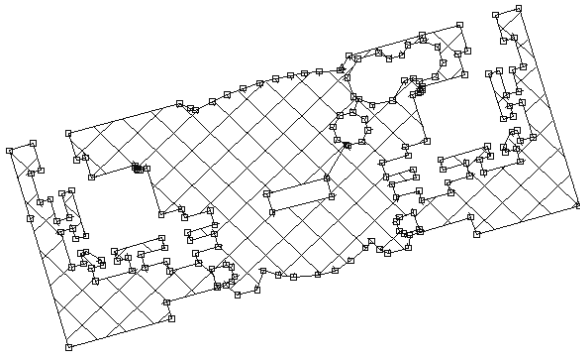


Fig 6 Object with multiple inner rings

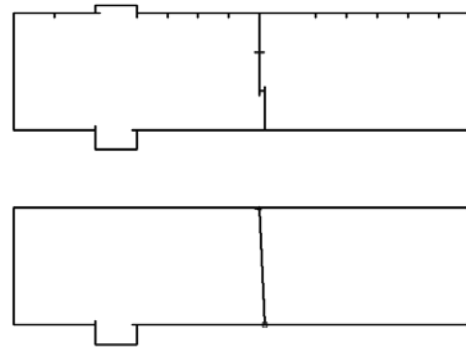


Fig. 7 Segmented and smoothed facades

Alternatively, GIS may organise buildings as multi-patch polygon parts consisting of several outer and inner rings (see Fig 6). The noise calculation software needs to convert this into barrier objects for the calculation. In the example above, facades had been digitised in GIS in small segments. This influences acoustic reflection as façade elements may not fulfil minimum reflector size criteria. Façades should therefore be smoothed to create simplified structures (see Fig 7) and adjacent walls between buildings must be treated identically.

Polygon Area Information

Several kinds of area objects are needed in the calculation, such as topography areas, attenuation areas or planning zones. The software should recognise the change in properties along the path of propagation. Sophisticated noise calculation software can handle this in a nested structure (e.g. patches of hard ground within larger soft ground area). Otherwise, overlapping structures need extra information to define hierarchies.

Topography areas help describe hard and soft surfaces to define acoustic impedance. To avoid over-complex modelling, some regulations assume hard surfaces on and next to the road in the propagation formula. So only more general areas need to be defined. However this will not cover the effect of noise propagation from a neighbouring road or other source types. Thus automatically generating road surface objects around existing road centre lines is helpful. However, the noise calculation software must then handle how these surface areas interact with the primary source in accordance with the regulation.

In several regulations, the attenuation effect of **attenuation areas** is calculated on the basis of the penetration length of a curved sound propagation path through the area. Often, these polygons will cover a large terrain area significantly structured by topography. The noise calculation software must interpret this either simply as a combination of horizontal attenuation blocks or in a more advanced manner as attenuation objects that follow the terrain. In some regulations, **planning zones** are used to define limiting noise exposure levels. Typically, the edges of such zones will run along the front façades of buildings. If it covers the

road space, undesired maximum values in conflict maps will occur. If placed on the façade itself, receptor points in front of the façade and related to it will be outside the planning zone, again creating possibly significant errors. GIS data may either be revised for that reason or the noise calculation software should use some criteria to find the proper receptor noise levels.

CREATING A 3-D MODEL BASED ON 2-D GIS GEOMETRY

As a general convention, just one height is given to buildings and horizontal roofs are assumed. When attribute information is used to assign heights as part of the post-processing, this height is typically assigned to the first node element of the building geometry. Starting position of polygons therefore need to be easily recognised or modified. Textual information, e.g. number of floors, that is not linked to buildings may be utilised when they are placed inside the building polygon. Sub-terrain buildings need to be excluded. If the noise calculation software can recognise podium buildings, the relevant receptor position in a noise map grid calculation can be placed on top of the podium.

A very different approach to transform 2-D GIS data into high quality 3-D data has been opened up since the advent of the use of airborne laser scanners to produce very dense topographic height information, providing z-data at an average distance of e.g. 3 m. This data can be merged with the GIS-given 2-D position of buildings. Filters are needed to eliminate misleading z-information caused by e.g. cars, advertising pillars or even street lights. As a final result of a highly automatic process a terrain model and building heights can be gained. When height information is assigned to 2-D data, the height definition for the different positions may vary. Input data is easier to define and check, when e.g. consecutive screen objects are digitised in the same sense of direction. This also eases input of screen surface properties which might vary for both sides of the screen. When GIS data has not been set up in this way, a tool is needed to automatically reorder the digitisation of elements into a homogeneous direction.

ROAD SOURCES

Roads representation in GIS may vary, e.g.:

- Centre line representing traffic of both directions
- 2 centre lines in same position with opposite direction
- Centre line with information about position of far lanes and central reservation
- Centre line of each lane in their correct positions
- Sealed surface area of the road space

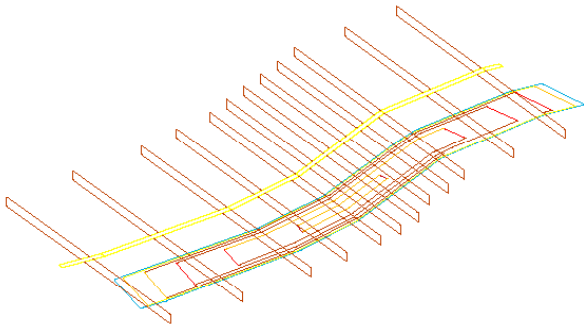


Fig. 8 A straight road segment and an area source automatically adjusted to the terrain

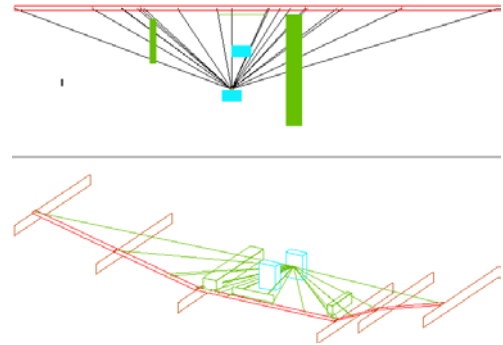


Fig. 9 Splitting of a line source by the “method of projection”

This can either be helpful or result in extra work, depending on the regulations used for the acoustic calculation. Tools needed in post-processing include:

- Splitting line elements as its properties change (e.g. on either side of a road junction)
- Creating parallel objects at a given offset (e.g. creating multiple lanes)

Heights will often just be defined as 0.0 m relative to terrain. Depending on the intention while digitising the roads their geometry will not have been coordinated with the shape of the terrain and tools for automatic adjustment of line or area sources are needed to prevent faults in noise propagation analysis (see Fig 8).

Simplifying road geometry leads to fewer barrier and road segments and significantly reduces calculation effort. However, the “method of projection” (Fig. 9) used in acoustic analysis can cause the sources to be split into sub-segments by barrier elements. Thus, the propagation of each sub-segment has to deal with more barrier elements. However, light smoothing can be applied. For simpler models or for air pollution, rough simplifications are used (Fig. 10).

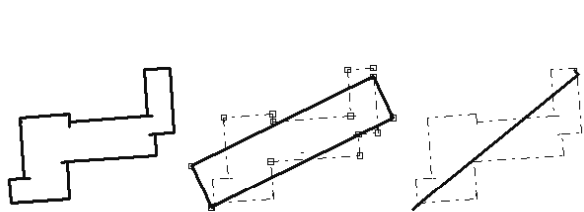


Fig. 10 Automatic rough simplification of geometry



Fig. 11 Collecting attribute data from simple geometry and applying to complex geometry

When 3-D road objects are smoothed, the vertical pitch (i.e. the minimum deviation allowable for non-segmentation) should be kept smaller than the horizontal one, to avoid a too large influence on diffraction. For 2-D road objects smoothing should be performed before any adjustment to terrain takes place.

Data are collected for the acoustic model from various sources, with varying attribute

information details and geometric accuracy. For example, a rough geometry might be available in traffic models and high quality geometry supplied from ordnance survey (see Fig 11). Matching these sources to link the traffic data to the detailed geometry can be supported by automatic tools driven by parameters like search distance, offset in direction, percentage of matching geometry, etc.. Results need to be checked for ambiguous geometry.

Geometric and attribute integrity of the model can be checked in various ways, e.g. visually:

- Attribute-related graphic display. For large models this can be augmented by fixed vector thickness independent of the scale of the display.
- 3-D visualisation. If only done in GIS, the noise calculation software should supply an import to help show how the model had been interpreted and used for acoustic calculation
- Tabular lists (primarily helpful in small models)

Automated numerical analysis is certainly needed for the more hidden errors in the model:

- Cross-digitising of building objects
- Unclosed polygons of area objects
- Forward-Backward-Forward digitised line sources or reflecting screens or facades
- Double objects
- Unintentional gaps between screens

Checking the Influence on Result Quality

Geometric manipulation can drastically influence calculation speed and result accuracy. When applied, it is recommended to validate their influence on the final results by performing sample calculations based on a detailed model comparing results to those from the simplified model intended for use. Software should provide random calculations of a user-defined percentage of grid points. The two sets of results may then be compared using statistical tools.

CONCLUSION

This paper has described several techniques for dealing with geometry from GIS systems in noise calculation. Existing GIS data may be a great aid for any large-scale noise mapping project. In its ideal form, GIS data, in terms of attribute and geometry management, have already been set up according to the demands of the particular project. Due to the intended multi-use functionality of GIS data, this will rarely be the case and tools for automatic or semi-automatic post-processing of attribute and geometry data will be needed for noise mapping. They have to be supplied by the GIS or by advanced noise calculation software. In other words, low to mid-range GIS products put higher demands on the post-processing capabilities of the acoustic software tool used.