3D noise models

A methodology to improve noise modelling and 3D visualisation of noise in urban areas

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NOISE pollution in large urban areas is considered as a serious environmental problem. Studies have shown that more than 20% of the world population lives under unacceptable noise levels. The problem is mainly caused by road traffic.

To assess the impact of noise, noise levels need to be predicted by noise computer models and represented on noise maps. GIS functionalities are commonly used to map and assess the impact of noise. An example of a noise map is shown in Figure 1 (Kluijver and Stoter, 2003). This figure shows noise levels along a road and railway. Current noise maps are in 2D representing noise levels, mostly as noise contours, on one selected height (for example at a height of four meters) from the surface.

A disadvantage of this method is the lack of insight in the three dimensional character of noise. In many situations noise levels at four meters do not represent the level at higher floors of a building correctly. The difference is especially large when the building is located close to the noise source or when a noise barrier is present. People living on lower floors of an apartment building benefit more from a noise barrier than people living on higher floors. 2D noise maps are insufficient to represent these situations. Consequently, 3D representations of the noise levels are needed. Several examples of 3D noise maps are known. Paris and Honk Kong already produced 3D noise maps (see Butler, 2004; respectively Wing and Kwong, 2006).

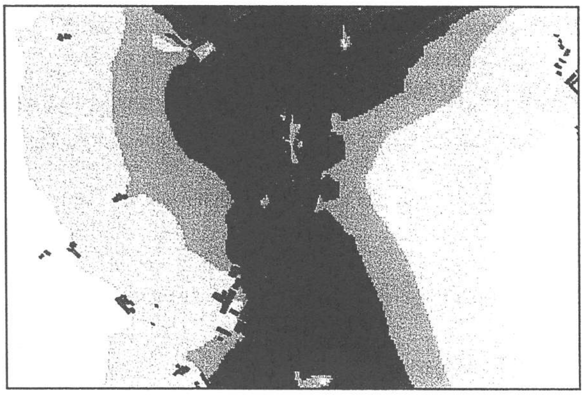

Figure 1: 2D noise map (Kluijver and Stoter, 2003)

The research presented in this paper is focused on a methodology to improve noise modelling and 3D visualisation of noise in urban area by applying 3D GIS. In our research (executed within the MSc programme 'Geo-information Science and Earth Observation for Environmental Modelling and Management', see http://www.gem-msc.org/), 3D GIS functionalities were incorporated in the noise prediction phase as well as in the phase of generating noise representations in 3D and using these representations in the noise assessment phase. For the 3D approach we studied both 2D interpolation methods to produce 2.5D representations - representing noise levels at a surface following the height of the terrain including buildings - and 3D interpolation methods to produce a full 3D voxel model of noise levels. It also reports on the methodology to generate the 2.5D and 3D representations using 3D city models. The results of the 2.5D and 3D noise representations are also presented. The 2.5D noise representation is applied to a real world noise application in order to show the improvements of a 2.5D approach compared to 2D noise maps.

3D GIS supporting 3D noise prediction

The area chosen for this research is located in the centre of the city of Delft, the Netherlands. Delft is a city of around 95,000 people in the densely populated South Holland province of the Netherlands. The population density in Delft is about 1,179 in-habitants per square kilometres. The study area is a small part of the city centre of approximately 30,000 m^2 and contains about 185 residential buildings with an average height of 15 meters.

A 3D city model covering the study area containing details of the buildings was provided by Vosselman et al., 2005. The city model, shown in Figure 2, is constructed based on an interactive segmentation of the parcel boundaries

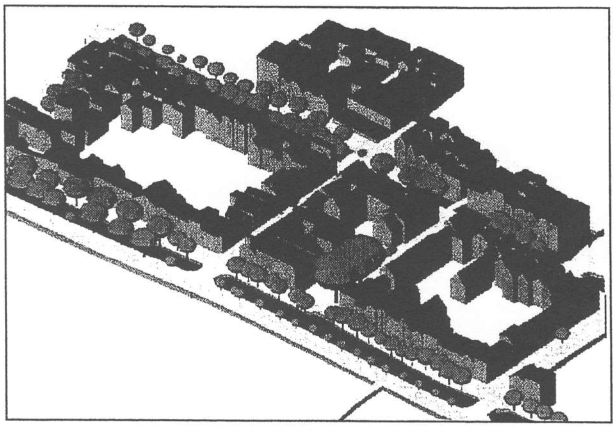

Figure 2: 3D city model of study area (Vosselman et al., 2005)

using several tools for splitting the polygons along height jumps edges. The roads, canals and trees were also reconstructed from the combination of parcel boundaries and laser altimeter data.

The 3D city model was used to build a 3D noise computer simulation model. Computer simulation models are used in most cases to determine noise levels. Computer simulations are preferred to noise measurements. There are several reasons for this. First of all, field measurements are time consuming since the noise levels concern the yearly averaged values and can only be done under the right weather conditions. In practise, it is impossible to execute an adequate number of measurements in order to produce reasonable noise maps. Furthermore, it is impossible to determine future noise levels by measurements except with noise simulation models to deal with future situations. In addition, models can predict noise levels within an acceptable level of uncertainty for most situations.

Therefore noise calculation software, implementing standardised and approved calculation methods, is widely accepted to provide reliable information on noise levels. These noise computer models calculate noise levels at 'virtual microphones' each of which is a point that re-ports what the noise level would be at a certain location under given circumstances. Heights of buildings, of roads and of other topography are taken into account in calculating the noise level at a certain x,y,z location.

We selected Standard Calculation Method 1 (a standardised Dutch method) to predict noise levels in our research since it takes into account the obstruction of noise by objects (such as buildings) but it is still relatively simple to use and can be easily integrated with GIS software. At the same time, it meets the requirements for our research (to see how 3D GIS can improve 3D noise applications). In the computer model, noise levels are computed on 3D data points based on:

a) information on the noise source (roads in our case): traffic intensity, maximum speed, road surface type, average emission of different vehicle types;
b) information on aspects that influence noise propagation such as noise obstruction by objects (like buildings or noise barriers) and noise absorption (like open areas with grass or bare soil);
c) distance and direction of the data points with respect to the location of the noise source.

A 2.5D noise representation was build by the following steps:

1) Positioning of observation points in the noise simulation software. The points were located in 3D on a surface following the terrain and buildings located on the terrain (see Figure 3 (a). Figure 3 (b) shows how points were positioned leaning slightly towards the buildings. This to avoid points that have same x,y,z coordinates which is not possible for 2D interpolation method (see step 3).
2) Calculating the noise level on the observation points (Figure 4);
3) Determining 2D noise contours with a 2D interpolation method using the levels on the 3D observation points (Figure 5). The z coordinate of these points was not taken into account during this 2D interpolation but is reintroduced in the next step;
4) Introducing the third dimension by draping the 2D noise contours on the city model. The 3D analyst tools of ArcScene were used to generate these 2.5D representations.

The 3D noise representation was built by the following steps:

1) Positioning of observation points in a 3D raster. In this raster of points, points may have same x,y but different z coordinates. The points are distributed evenly with equal intervals in both horizontal and vertical directions (2

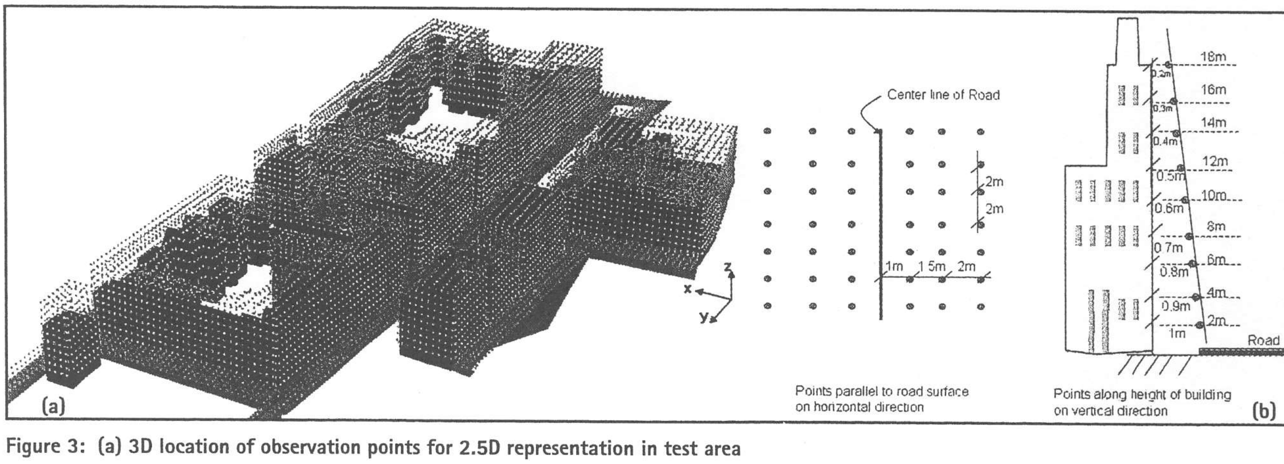

Figure 3: (a) 3D location of observation points for 2.5D representation in test area (b) spacing of points on horizontal and vertical direction on front side of buildings

m) in 'lines' parallel to the roads.

2) Calculating the noise level on the observation points.
3) Determining the 3D solid noise model with a 3D interpolation method. With this method an extra step to reintroduce the third dimension is not necessary.

For both methods, the positioning of the points was based on the following considerations:

- Noise contours are expected to be parallel to the roads and points located in a pattern parallel to the road can reflect this behaviour most optimally.
- Care was taken not to place points inside buildings, because buildings act as blocking objects in the model and these points would produce low levels which are not representative for the levels on the façades of the buildings.

Results of a 3D approach for the representation of noise levels

The result of 2.5D representation of noise levels is shown in Figure 6. Although current noise simulation models predict noise levels in 3D, the output of the models, being a point data set with computed noise levels, cannot be used directly for meaningful 3D visualisation or 3D analyses. In order to utilize the 3D information of noise software output, noise levels need to be visualised understandably using the third dimension of the observation points. From Figure 7 it can be seen that the 2.5D approach is able to add this extra dimension to the output of noise models. The 2.5D representation offers insight into the effect of noise at any particular height on the terrain surface and on façades of buildings: high noise levels occur on road surfaces and low noise levels occur on top and backside of buildings.

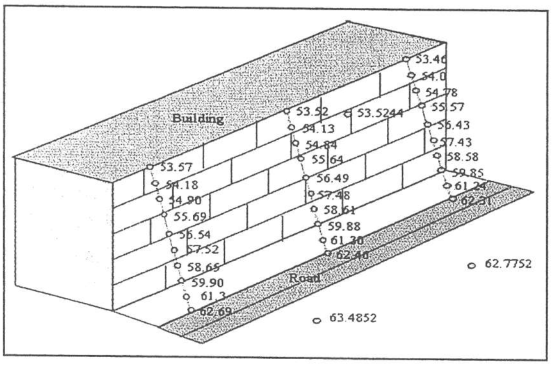

Figure 4: Observation points near buildings with computed noise levels

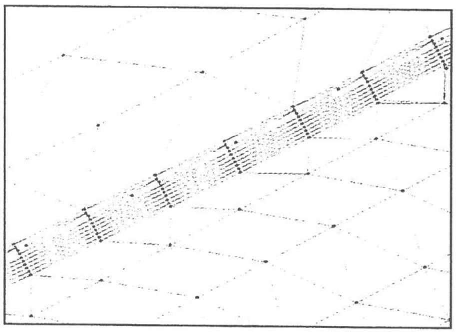

Figure 5: TIN interpolation on the points leaning towards a building (top view)

For this 2.5D representation, different interpolation methods were applied and compared to conclude on the best suitable method for generating 2.5D noise representation. In our research, TIN (Triangulated Irregular Network) was indicated as the most suitable method for the generation of 2.5D noise representations. The explanation for this is that TIN can deal very well with the irregular distribution of observation points as present in our point data set when looking from above (Figure 5). More triangles with relative small sizes are generated at locations with higher point density. The other methods considered in our research (Inversed Distance Weighted interpolation, Natural Neighbourhood Method and Kriging) are all based on a weighted-average method resulting in a grid structure with equal cell sizes for the whole area. However, more trials with different approaches for point densities should be made to be able to draw thorough conclusions.

The 3D noise representation is a solid model representing attribute values in the form of 3D grid cells, called voxels. These attribute values are the result of spatial interpolation in three dimensions based on the calculated values on the observation points. Currently very few commercial GIS software provide tools for 3D interpolation for 3D point data. Most existing tools are for hydrology, geochemical, geophysical, geotechnical or lithology studies and they are based on borehole data. Examples are GOCAD, Environmental Visualization Systems (EVS), Rockworks, and GRASS. Only the FIELDS software (Field Environmental Decision Support tools, extension of ArcView 3.5; FIELDS, 2007) was applied successfully in our research. GRASS can also be used for interpolation of 3D point data but had a limitation concerning amount of input points.

In the 3D IDW method implemented in FIELDS, the searching ellipsoid-body is used to find the known points that will contribute to the interpolated value. The true, 3D distance between points is used to determine the weights of the known points. The user has to define parameter values to define the shape and size of the ellipsoid-body. It is obvious that compared to 2D it requires more expertise to guide the 3D IDW process.

The result of the 3D interpolation is presented in Figure 7. Due to limitation of software it was not possible to display the 3D city model together with the 3D solid noise model. However, it was possible to clip the model using the polygon layer of roads. Figure 8 shows that noise levels on the main as well as on the interior roads can be analysed in 3D using the solid model. This representation clearly shows the pattern of noise levels above the road surface in all directions. It shows high noise levels at the middle of the road and gradually reducing noise levels with increasing 3D distance from the centre line of road.

From our experiments we can conclude that true 3D interpolation looks promising, since it reflects the three dimensional character of noise. Therefore the 3D model offers good possibilities for noise experts to improve insight into 3D noise propagation and the way this behaviour is implemented in current noise computer models.

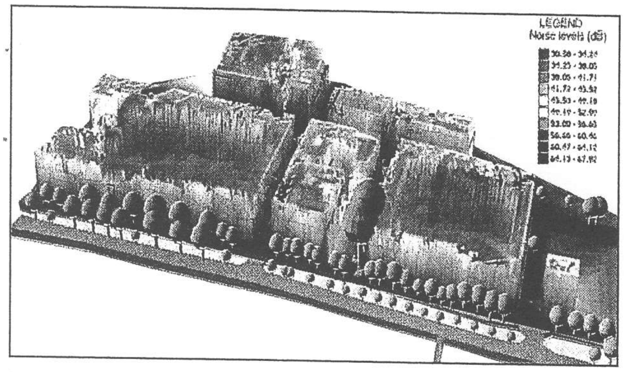

Figure 6: 2.5D noise representation obtained with TIN interpolation

However, 3D modelling of attribute values is still in developing stage. For example, the following are the limitations in the FIELDS software:

- The software does not have tools for spatial analysis. It is difficult to identify noise levels at a particular height.
- It is not possible to generate 3D contours.
- The 3D noise representation cannot be presented together with the 3D city model. Consequently, it is difficult to locate and orient oneself.
- The solid model requires specific interaction functionalities (e.g. slicing) to be able to analyse the values at all locations.

Although these findings indicate limitations specific to this software, the last three can be indicated as more general limitations that currently apply to solid models representing at-tribute values in 3D.

Application of 2.5D noise representation

In our research, the possible benefits of a 2.5D approach compared to 2D noise maps were tested by applying it to the assessment of the reduction of noise levels by noise barriers.

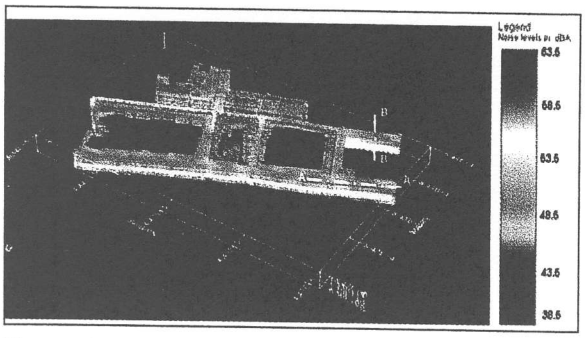

Figure 7: Volumetric view of noise levels on the road surface of study area.

Figure 8 shows the effect of seven different noise barriers varying in height, width and distance from the road. The details of the different barriers are shown in the bottom left corner of the figure.

The first three barriers (a), (b), (c) are of height 3 m and located at a distance of 3 m, 6 m, and 9m, respectively, from the edge of the road. As can be seen in Figure 13, the effect of the barrier reduces when the distance of the barrier to the road increases. Furthermore, it shows that there is no effect of the barriers on higher floors.

The next three barriers (d), (e), (f) are of different heights (2 m, 3 m, and 4 m respectively) and located at an equal distance of 5 m from the edge of the road. Figure 13 shows that noise reduction due to the noise barriers increases when the height of the barrier increases. Still no effect of the noise barrier is found at the higher floors.

Barrier (g) is located where there is no building. Barrier (g) shows therefore the effect on the ground surface.

This case study shows that a noise barrier should be high enough and sufficiently close to the road to have a reducing effect for all floors. A 2D map representing the noise level for only one height (close to the surface) cannot provide this information. Noise levels on lower floors could be overestimated and on higher floors underestimated.

Conclusions and future work

As can be concluded from this paper, 2.5D noise representations offer many improvements compared to traditional 2D noise maps. A 2.5D representation provides insight into noise behaviour with respect to height. As a result, more accurate assessment of noise impact is possible in particular when different floors of a building or noise barriers are concerned. Since 2.5D representation is easy to 'understand' they are beneficial for communication purposes in city planning processes with the broad public.

The study presented in this article showed that general available 2D interpolation methods in combination with 3D GIS can be used to produce 2.5D representations of noise levels.

An advantage of a 3D noise representation is that even more accurate information can be given on the three dimensional character of noise which is the propagation of noise in all directions. However the studied 3D software do not provide the desired performance. The software could not handle the large number of observation points that are common as output of noise simulation models and could not provide the required integrated visualisation of noise levels and contours with the 3D city model. In addition, 3D spatial analysis functionalities were lacking. Further development of functionalities is needed concerning 3D interpolation, 3D visualisation of continuous data and 3D analysis. If major progresses in these areas are achieved, 3D representations provide more thorough understanding of noise propagation and 3D noise effects.

Improvement in visualisation suggests an improvement in accuracy. Although this article shows that this is certainly the case in studying noise on different floors or behind a noise barrier, a warning is appropriate. The accuracy of noise models is dependent on the whole noise modelling process starting from available data. Accuracy is influenced at each operation such as during generation of observation points, spacing of points, noise calculation, spatial interpolation and analysis. Ambitions for further improvement of visualisation are obviously supported by the authors but not without emphasising the need for error assessment

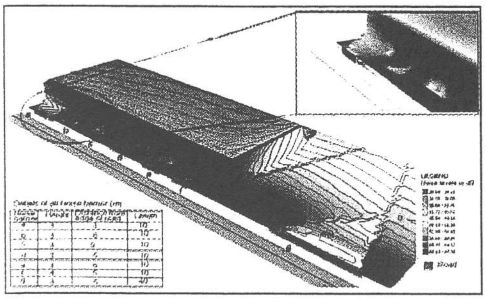

Figure 8: Effect of noise barriers.

and presentation of the uncertainties.

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Galileo update

Partial funding through EU farming subsidies

Following months of disagreements, the EU has reached a funding compromise and resolved the crisis around its Galileo satellite navigation system. Two thirds of the missing 2.4 billion euros will be provided from EU farming pots alone. This was announced by the Portuguese Chair of the European Council in Brussels on Friday night following more than 12 hours of budget negotiations for 2008 by the EU Ministers of Finance or their representatives.

Germany could not uphold its reservations against fully funding Galileo from the EU budget, reported EU diplomats. Berlin didn't want to put the EU's long-term financial plan on the line, which runs until 2013. According to German Minister of Finance Peer Steinbrück, the German government was also apprehensive of straining its national budget by an additional more than 500 million euros.

European Commissioner for Financial Programming and Budget Dalia Grybauskaite spoke of an "important decision". As she had suggested, farming subsidies would for the first time be used to improve the EU's competitive position. The current Chairman of the Council of Ministers, Portuguese State Secretary of Finance Emanuel Augustos Santos, said that farming subsidies had not been exhausted this year, and that therefore nothing would be taken away from anybody.

This compromise has also finalised the EU budget for the coming year. Payments are to increase by 4.2 percent to 120.346 billion euros. The funding compromise also includes the European Institute of Technology (EII). The EIT's intended purpose is to connect the research departments at top European universities and in industry from next year. *http://www.heise.de/english/newsticker/news/99568*

EU Commission modifies Galileo tender rules

The EU Commission will make a new call for tenders for the Galileo project that will limit each bidding company to two segments of the project, Handelsblatt reported, without saying where it got the information.

The planned European satellite navigation system will be split into up to seven different segments in a move to help appease the German government's concern domestic companies may be at a disadvantage in the bidding process, the newspaper said.

The Commission also said in an internal document the newspaper obtained it will take into consideration the fact that Germany made considerable contributions to the project's test and development phase.

The EU and a consortium of companies that is to develop Galileo will still need to agree on funding of the 3.4 bln eur project.

The consortium -- which includes EADS, Alcatel-Lucent, Thales, Inmarsat and Finmeccanica SpA -- is reluctant to sign a contract requiring it to fund two-thirds of the project. *http://www.hemscott.com/news/latest-news/item.do?newsId=53878217738623*