A framework for improving urban noise map

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Abstract

With increase of urban noise, urban planning and design use noise maps increasingly, and 3D noise map are also paid attention increasingly. This paper investigates the possibility of developing a 3D(three-dimensional) acoustic interactive scene base on VRGIS platform for the creation of noise maps. This involves building simple 3D city model, generation of 3D observation points and noise calculation using standard noise calculation models. Beijing Olympic Center was selected as study area, fictitious data was used to calculate the noise levels of study area. Appropriate spatial interpolation methods were used to develop noise surface. Measurements were also carried out at various locations throughout the test area, which were then used to investigate the accuracy of predictions.

Keywords: VRGIS Platform; Environmental noise; Noise mapping

1 Introduction

Currently, noise pollution in urban environment is one of the serious issues of concern[1]. The spatial pattern of urban noise and its acoustical characteristics are important for the acoustic asssessment to establish policies to reduce the hazardous physical or mental effect[2]. To minimize the effect of noise, the EU has established and accepted DIRECTIVE 2002/49/EC, seeking to develop a common European-wide strategy regarding the management, control and assessment of environmental noise, the Directive calls for the creation of strategic noise maps for designated areas[3].

The phenomena of noise involve spatial distribution and dynamic process, so the GIS(Geographical Information System) can provide the central database management in the development of a noise map[4]. The mapping approaches supported by a GIS can be combined with comprehensive analysis. The 2D(Two Dimensional) noise maps are developed with the information of noise levels on particular height, however, noise transmits in all direction and the impact of noise is in all direction[5].

Advances in computer graphics hardware and algorithms, visualization, and interactive techniques for analysis offer the components for a highly integrated, efficient real-time 3D Geographic Information System. We have *developed* VRGIS(Virtual Reality Geographic Information System) platform with truly immersive capability for navigating and understanding complex city, the virtual urban scene based on VRGIS provides the possibility to simulate three-dimensional noise map[6], which can be generated by designing plug-in and dynamically rendering the spatial and temporal noise distribution data while simulating.

In this study, a framework to develop a noise map based on VRGIS platform has been suggested. The accuracy of noise map depends on the methodology used to develop it. The methodology should be easily understood by others and able to be implemented again at any site conditions. Aiming to these points, the methodology of this research is well planned and executed in a systematic way. The flow chart of the methodology is shown in Figure 1.

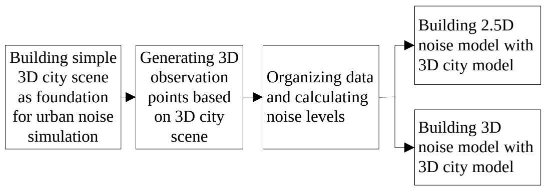

FIGURE 1 The methodology to building 2. 5D and 3D noise map.

2 Study area and data description

2. 1 STUDY AREA

Beijing olympic center, China was chosen as a study area. The chosen area containing 29 roads and 131 buildings. Most of the buildings of study area are with gable and hip roof. The location of study is shown in Figure 2. The research is mainly focusing on methodology development so it can be applicable to any study area. A 3D city model which has detail information about the buildings, roads, open area was required for virtual noise simulation.

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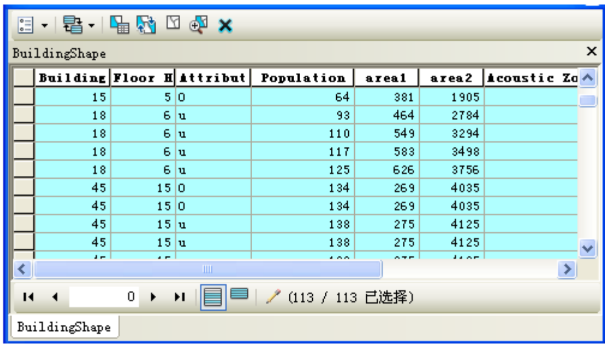


Building	Floor H	Attribut	Population	area1	area2	Acoustic Zo
15	5	O	64	381	1905	
18	6	u	93	464	2784	
18	6	u	110	549	3294	
18	6	u	117	583	3498	
18	6	u	125	626	3756	
45	15	O	134	269	4035	
45	15	O	134	269	4035	
45	15	u	138	275	4125	
45	15	u	138	275	4125	

FIGURE 2 The study area and building details.

2. 2 DATA FOR NOISE CALCULATION MODEL

One of the main factors to be considered cautiously in noise mapping is the assumptions and specifications of input data[7]. This esearch experiments with fictitious data that means the results cannot be validated with actual field condition.

The input data for noise calculation is assumed to be similar to that of field conditions. The factors such as meteorological conditions, air absorption, source strength variation, ground attenuation effect and barriers, and reflection were not considered for noise calculation[8]. The following are the assumption of input data for the developed noise mapping model .

Assumption for traffic data:

- The road traffic includes all types of vehicles such as small vehicles, middle vehicles and heavy vehicles.
- The noise is emitted from the centreline of roads.
- The type of road surface is same in the entire study area and it is assumed to be asphaltic concrete.
- The road surface of study area is flat without any undulations in ground surface.

Assumption for building data;

- All the buildings have same type of construction material
- The built-up area will be assumed acoustically hard because it is easy to check in the field.
- There is no occurrence of noise due to façade effect from the wall of the buildings.

Assumption for noise absorbing area like open ground;

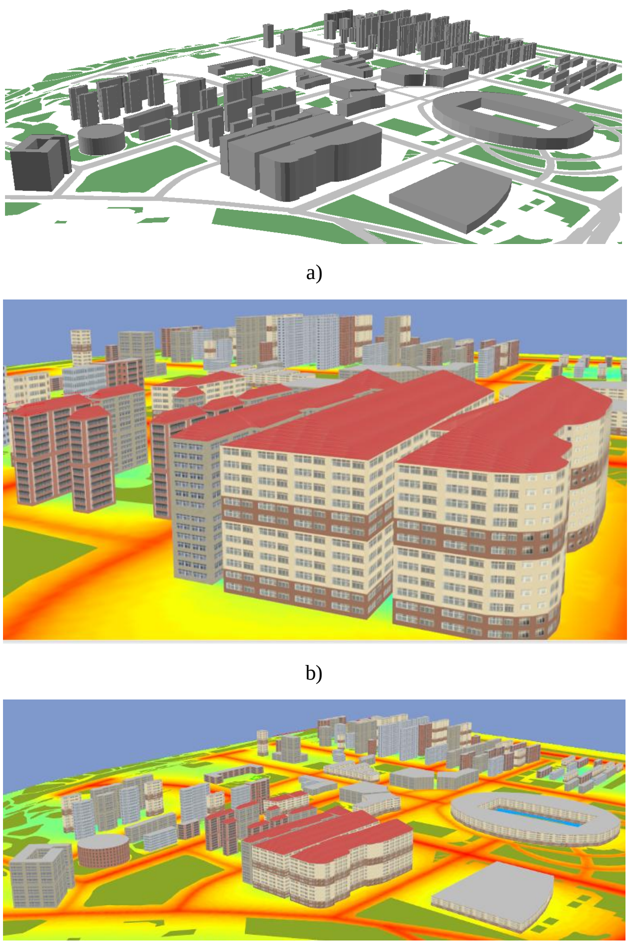
- The noise absorbing areas such as road material, trees and water is not considered in the noise calculation model.
- In the noise calculation, only the noise from road traffic is considered not the background noise.
- During noise calculation it is assumed that there is no noise barriers located in the study.

3 3D Buildings as Foundation for Urban Noise Simulation

3. 1 LOD OF 3D BUILDINGS

The plugin-in scheme of VRGIS platform has provided the opportunity to create 2. 5D and 3D noise map, 3D maps of urban acoustic environment can provide a base for understanding of noise pollution and its assessment. 3D buildings is the basis for all city models and their consequent usage, LOD(Level of Detail) techniques[9, 10] is adopted to draw 3D buildings at different resolution depending on the demands of noise visualization, includes LOD1, LOD2, and LOD3. LOD1 is the building with flat roofs, LOD2 is the building models with roof forms, and LOD3 is the architectural models with façade texture and proper building geometry. In order to deploy 3D city, several factors must be taken into consideration.

- Efficient modelling of existing buildings that are already present;
- Establishment of efficient workflow processes for creating 3D city models, from LOD1 to LOD3
- Automatic generation of LOD1 and LOD2 models in order for them to be economically feasible on a large-scale;
- The aforementioned models must be accurate with respect to building heights and geometry in order to serve as the basis for urban noise simulation or mapping.



a)

b)

c)

FIGURE 3 LOD of 3D building:
a) LOD1 – block models with flat roofs,
b) LOD2 – block models with simplified roof structures,
c) LOD3 – architectural models with fasade texture and proper building geometry.

3. 2 THE PROCESSES OF CREATING 3D CITY MODEL

VRGIS platform has prepared the 3D city modelling to describe the 3D complex noise environment, beyond the modelling of topographic data the 3D modelling can also extend to geo-referenced data[11]. It comprises the basci 3D model, the computational simulated façade noise grid model and the photorealistic 3D model in the urban area. The 3D model is developed according to the GIS data for building, roads, terrain, podiumns and barries.

The process of three-dimensional building resconstruction based on high-resolution building height models and building footprints indeed offers a high-degree of pricision

A digital terrain model, building footprints and a digital elevation model are used as the basic data components for the automatic extrusion of 3D building models. These three data elements produce as result block models with simplified roof geometry which can be used for noise mapping.

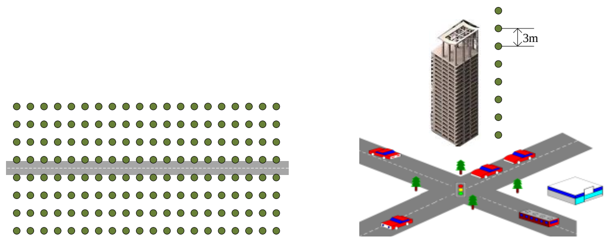
Because roofs are normally in their nature complex, a catalog of the most common simple rooftypes is necessary. Thus the software is able to reconstruct basic forms such as flat, pitched or hipped roofs. Here both distance and roof slope are estimated. The roof forms of single cells created during the reconstruction process are afterwards adapted for the total roof form of the building. A parametric estimation provides a description of the outer edges of the reconstructed building, which can be then be attributed as a 3D shape file.

The procedure to reconstruct a very large number of buildings differs thus substantially from other semi-automatic procedures where a manual intervention is necessary. For errors found during the reconstruction, anywhere between 15-25 percent depending on the data inputs, an interactive operator enables the correction of building geometry and basic roof forms within the data set. The input dataset is ground cadastral map as 2d shape files, output 3D city scene includes 3D buildings, green, and roadnetwork.

4 Noise data orgnization for visualization

4. 1 GENERATION OF 3D OBSERVATION POINTS

The most important operation is generations of 3D observation points[12]. These observation points represent location where the noise levels are to be calculated. The scale and density of this observation should be sufficient enough to reach adequate accuracy in the final results. But the decision about the spacing of observation points is difficult task. There is no standard for spacing of observation points. However, densely location of points can produce adequate results. In this research the spacing of observation points are designed based on the interview with *Beijing Municipal Institute of Labour Protection*. High density of observation points were selected on the road surface and gradually reducing in spacing with distance away from the source. FIGURE 4 shows the spacing of observation points along parallel to road as well as along the height of the buildings. The points are distributed evenly with equal intervals in both horizontal and vertical direction. The points on horizontal direction are selected at 2m above from road surface. The points in vertical direction are in straight line with 3m interval. Vertical points are arranged with an offset of 1m leaning towards the buildings . In order to avoid extrapolation, excess observation points are selected on the face of the wall than the actual height of buildings.



a) b)

FIGURE 4 3D observation points:
a) Points parallel to road on horizontal direction,
b) Points along height of building on vertical direction.

4. 2 DESCRIPTION OF DEVELOPED NOISE CALCULATION MODEL

The noise map modeling was carried out by entering a series of data into the systme and required various steps. The details data of buildings, road network, green, noise barrier if any, and observation points are requried for noise calculation. The process includes a) Define the traffic flowfor each road or street: flow of light and heavy vehicles, speed, etc. b) Set the modeling scenario: streets, buildings, contour lines, etc. c) Choose the most appropriate prediction model. d) Produce the noise map by software modeling. e) Verify by field measurements.

In the developed model the source emission model and the propagation model are completely separate, thus it is possible to determine the level of sound attenuation independently from the original source level.

The level of noise resulting from a flow of road traffic was calculated following the China Ministry of Transportation recommended noise model for road traffic, which is the specifications for environmental impact assessment of highways of china (JTJ 005—96). Vehicle flow and traffic compositon are the main factors, the road traffic flow is divided into heavy $(L_{Aeq})_H$, middle $(L_{Aeq})_M$ and light $(L_{Aeq})_L$ three types. The following expression has been used:

$$L_{Aeq}=10\lg\left[10^{0.1(L_{Aeq})_H}+10^{0.1(L_{Aeq})_M}+10^{0.1(L_{Aeq})_L}\right]-\Delta L_1-\Delta L_2 . \quad (1)$$

Where:

L_{Aeq} is the the equivalent noise level at receiver point in decibel.

ΔL_1 is the traffic noise correction caused by road curve or finite length.

ΔL_2 is the traffic noise correction caused by the obstacles between road and receiver point.

$(L_{Aeq})_H$, $(L_{Aeq})_M$, $(L_{Aeq})_L$ is the equivalent noise level at receiver point from heavy, middle, light traffic type in decibel, and can be calculated with the following equation:

$$(L_{Aeq})_i = L_{W,i} + 10\lg\left(\frac{N_i}{v_i T}\right) - \Delta L_{div} + \Delta L_{slope} + \Delta L_{surface} - 13. \quad (2)$$

$L_{W,i}$ is the average vehicle radiation sound level at the 7. 5m distance produced by i type vehicle.

N_i is the traffic volume (vehicles per hour) of i type vehicle.

v_i is the average speed (km/h) of i type vehicle.

T is the time of $L_{Aeq,}$ usally is 1 hour.

L_{div} is the distance attenuation, which can be accounted for by $A_{div} = 10\log(4\pi d^2)$, d is the distance between noise equivalent lane and receiver.

ΔL_{slope} is the traffic noise correction caused by road slope.

$\Delta L_{surface}$ is the traffic noise correction caused by road surface.

This empirical equation is able to predict the equivalent levels generated by the vehicle flow in the main roads with an accuracy of $\pm 3dB(A)$.

5 The framework based on VRGIS platform

5. 1 FRAMEWORK

With the rapid development of city, the traditional way, which based on digitization of hardcopy maps and data entry, to prepare data for urban noise map is not quite viable. With the wider availability of digital data, GIS (Geographic Information System) has been customized to prepare, compile, process, manage and store the large quantity of spatial data including the road networks and traffic data, buildings and topographic information.

GIS is a computer-based tool for mapping and analyzing phenomena that exist and happen on the surface of the Earth, at the same time, advances in computer graphics hardware and algorithms, visualization, and interactive techniques for analysis offer the components for a highly integrated, efficient real-time Virtual Reality Geographic Information System. We have developed VRGIS (Virtual Reality Geographic Information System) platform with truly immersive capability for navigating and understanding complex city, the virtual urban scene based on VRGIS provides the possibility to simulate three-dimensional noise map, which can be generated by designing plug-in and dynamically rendering the spatial and temporal noise distribution data while simulating.

VRGIS platform could be used to track data manipulation at each stage of proces, includes changes in input data, data simplification, interpolation methods, calculation methods, calculation settings, and some factors which could influence the accuracy of results. At the same time, VRGIS facilitates the visual presentation of the noise effects and provides an additional tool for analysing the results, as shown in Figure 5.

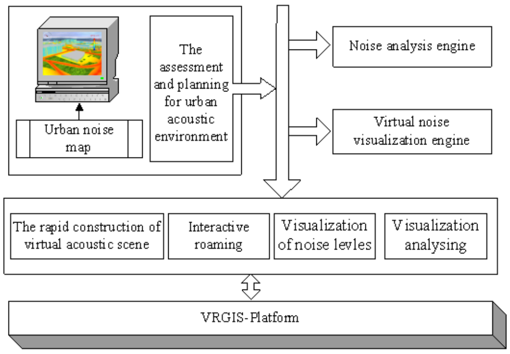


FIGURE 5 The framework based on VRGIS platform.

The integration of VRGIS with noise model can provide accurate and visualized assessment of the environmental impact of noise. GIS Database management system facilitates for storing, collecting, controlling and managing the noise data. Urban noise map can be generated based on the interpolation techniques available in GIS. It is possible to generate a continuous spatial model of noise levels within VRGIS. Finally, VRGIS platform also provides a convenient environment to present noise maps on internet web pages for making information available to the public .

5. 2 THE IMPROVED URBAN NOISE MAP

Using the above-mentioned noise mapping improved method, we obtained the simulation output displayed in Figure 6. a) is the rendering result of three-dimensional noise map on day noise value, b) is the rendering result of three-dimensional noise map on night noise value, and the gradient color from blue to red represents the noise distribution rendering result. It can be figured that the color is redder beside the high-traffic roads. And on the low-traffic roads, high noise level only distributes around individual vehicles.

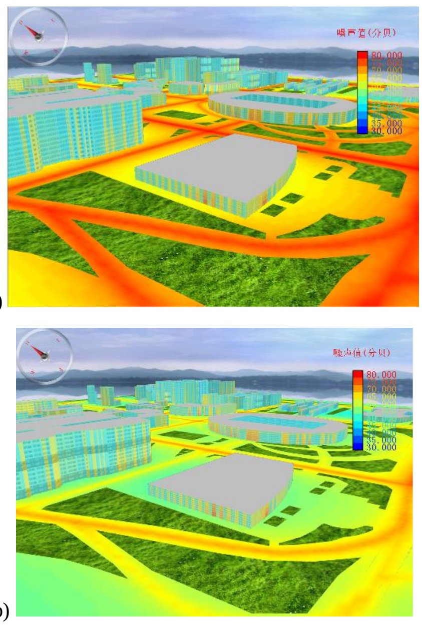
a)

b)

FIGURE 6 The three-dimensional urban noise map:
a) Noise value of day; b) Noise value of night.

6 Conclusion

In this paper, a 3D acoustic interactive scene based on VRGIS platform is investigated, and Olympic Center was selected as study area. The creation of urban noise map includes building simple 3D city scene as foundation for urban noise simulation, generating 3D observation points based on 3D city scene, organizing data and calculation noise levels, and finally, building 2. 5 or 3D noise model with 3D city model. The urban noise map of study area has fluently demostrated the noise distribution of urban area and presented its validataon.

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