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Web enabled spatio-temporal semantic analysis of traffic noise using CityGML

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Abstract: Indian population is growing very fast and is responsible for posing various environmental risks like traffic noise which is the primitive contributor to the overall noise pollution in urban environment. So, an attempt has been made to develop a web enabled application for spatio-temporal semantic analysis of traffic noise of one of the urban road segments in India. Initially, a traffic noise model was proposed for the study area based on the Calixto model. Later, a City Geographic Markup Language (CityGML) model, which is an OGC encoding standard for 3D data representation, was developed and stored into PostGIS. A web GIS framework was implemented for simulation of traffic noise level mapped on building walls using the data from PostGIS. Finally, spatio-temporal semantic analysis to quantify the effects in terms of threshold noise level, number of walls and roofs affected from start to the end of the day, was performed.

Keywords: CityGML, Traffic noise model, Web GIS, PostGIS, Spatio-temporal semantic analysis

1. Introduction

Noise has always been a main cause of irritation and distress for the people in metro cities. The traffic noise, being the main cause of noise pollution, is considered to be of uttermost importance and must be analyzed for the mitigation of noise pollution. Sound propagates in all directions and its intensity is affected by many sources and barriers so, to quantify the effects it is necessary to study the propagation and the effects of sources and barriers on the propagation of noise (Lamure, 1986). The main sources of noise on a vehicle include i) Engine noise ii) Noise from transmission and silencers iii) Noise due to road surface contact. Important factors that reduce the overall noise level include i) Wind as a barrier ii) Road surface absorption iii) Noise barrier walls (Lamure, 1986) Various methods and models have been developed to accommodate for all these attributes that are responsible for generation and propagation of traffic noise. Several models have been developed for different countries all over the world and this heterogeneity lies due to the variation of traffic conditions and other modelling parameters like types of vehicles in the country, types of roads and also meteorological conditions etc. These models aim towards simulation and prediction of traffic noise levels to facilitate planning and designing of road and surrounding infrastructure or to estimate the behavior or impact for different traffic conditions. Due to heterogeneity in traffic conditions and other parameters, many kinds of models have been proposed. Suksaard et al. (1999) considered only two classes of vehicles to model the traffic noise impact. Lam and Tam (1998) proposed a noise prediction model based on Monte-Carlo approach. Later, various studies were proposed that used GIS for analyzing traffic noise and development of traffic noise prediction models (Li et al., 2002; Pamanikabud and Tansatcha, 2003). A statistical model was proposed by (Calixto et al., 2003) to estimate road traffic noise in an urban setting (Cirianni and Leonardi, 2012). Some of the standard models that should be addressed include Dutch noise calculation methods Italian C.N.R. model, TNM by FHWA in the US (U.S. Department of Transportation & Federal Highway Administration 2011), A French model that is NMPB, CoRTN and PRTN developed by the Department of Environment in the United Kingdom, RLS-90 by the Germany (WSEAS International Conference on Applied and Theoretical Mechanics et al. 2009). Recently the traffic noise modelling trend is moving towards 3D modelling approach as the noise propagates in all directions so its simulation in 3D is essential to provide a realistic view of the conditions and analysis of complete scenarios that can arise in reality. Some of these studies include a motorway traffic noise model based on local traffic conditions in Tehran by (Reza Ranjbar et al., 2012). In this study noise impact on the building and ground surfaces are shown 3D format. Pamanikabud and Tansatcha (2010) demonstrates 3D analysis to investigate the traffic noise impact on building and surrounding area of a motorway. Schrenk (2008) demonstrated 3D visualization of a noise map within an urban street canyon.

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3D data representations

The attributes for visualization of any 3D model can be generally divided into three parts that is geometry, appearance and scene. The geometry is always stored as a set of 3D points. These points (or vertices) can be combined to form lines, polygons and other geometries. Many models have been proposed in past for an efficient 3D data representation. 3D object representations are classified as surface-based and volume based (Li, 1994). In surface-based representations, object is represented by any of the surface primitives like are grid, shape model, facet model and boundary representation (B-rep) etc., whereas, volume-based representations are 3D array, 3D TIN (or TEN), octree, Constructive Solid Geometry (CSG) etc. B-rep assumes point, edge, face and volume as representation primitives and defines objects as a combination of these primitives. In this approach, surface is represented as a set of faces and the number of vertices in the face can vary from two in case of lines, three in case of triangulated surface or more (McHenry and Bajcsy, 2008). B-rep model represents an object in the form of a mesh to form boundary of an object (Murali and Funkhouser, 1997). It also defines the topological relationship among faces of a solid object making it a closed space in 3D environment. One of the disadvantages of B-rep is that, to represent non-planar surfaces, functions like B-spline that are very complex and computationally expensive has to be utilized. A 3D spatial model is an aggregate of geometric and topological model. In recent years, many topological models have been proposed based on the above mentioned data models such as Tetrahedral Network (TEN), Urban Data Model (UDM), and Simplified Spatial Model (SSM) etc. (Sakkalis et al., 2000; Vivoni et al., 2004).

CityGML: Semantics and Level of Details (LoD)

The modelling and analysis of 3D space at semantic level including aboveground and underground, indoor and outdoor environment, is necessary to offer an optimum total solution (Zang et al., 2011). 3D city models are gaining popularity in geospatial modelling and mapping domain as these provide various advantages for many dynamic user applications. These are shared among various tools and applications which can apply different approaches and work on different formats for analysis. Every approach has certain advantages and disadvantages for specific applications. To utilize the same city model within these different applications, an interoperable and platform independent representation format is a necessary requirement. An interoperable data model can be easily generated from and converted to other data models. CityGML has been proven to be the solution to this issue (Kumar et al., 2015). The degree of data quality required for any city model depends on its intended application and the data collected for that application. This requirement of different levels of data quality must be reflected by the concept of different Level of Detail (LoD) (Joachim et al., 2013). CityGML is a semantic information model that supports the same object representation in different LoD simultaneously (Saran et al., 2015), enabling analysis and visualization of the same object with regard to different degrees of resolution. Also, two CityGML data sets containing the same object but in different level of detail may be combined and integrated (Kolbe et al., 2005). The CityGML LoDs (Wate et al., 2013) are discussed below,

1. LOD0: This is the basic and coarsest level of representation and is considered as a 2.5D Digital Terrain Model (DTM). The foot print polygons of urban features like buildings generated from the ortho-imagery are draped over the terrain to create the 2.5D representation model.
2. LOD1: This is a well-known blocks model, without any roof structures. This level is used for city and region level coverage. This model is useful for representation and analysis over a large area.
3. LOD2: This level has distinctive roof structures and larger building installations like balconies and stairs. This level of detail is suitable for district/city level projects.
4. LOD3: This is the highest level of representation for external features of the urban objects. It denotes architectural models with detailed wall and roof structures, doors, windows and bays etc.
5. LOD4: This completes a LOD3 model by adding interior structures like rooms, stairs, and furniture.

CityGML also supports the extension of schema to support interoperability of application specific attributes through Application Domain Extension (ADE) mechanism. Many ADEs have been proposed, such as, Energy ADE (Krüger and Kolbe, 2012), ADE for urban solar potential (Wate and Saran, 2015), ADE for multi-utility network (Becker et al., 2013), ADE for facility management (Moshrefzadeh et al., 2015) to support the interoperability of thematic attributes.

3DCityDB

3DCity Database abbreviated as 3DCityDB is distributed in two versions, one version for Oracle Spatial and another for PostGIS. Here the PostGIS version is discussed and utilized as part of this work. 3DCity Database is a fully Open Source software which has the ability to store and analyze CityGML documents in PostGIS. It consists of a database schema to support CityGML data structure along with procedures used by importer/exporter tool that comes with the 3DCityDB package. The key features of

3DCityDB are, it is semantically rich, hierarchically structured model, supports all five level of details, fully supports CityGML1.0 and 0.4.0, and xml validation of the CityGML documents is also possible (Kunde et al., 2013).

2. Study area

For 3D model reconstruction, visualization and analysis, Dilaram chwok on Rajpur road and its surrounding region bounded between 78° 2' 55.4532" to 78° 3' 18.5328" East longitudes and 30° 19' 50.124" to 30° 20' 12.732" North latitudes was selected. The map constructed using the LISS-IV imagery with vectors layers for roads and buildings overlaid on top, is shown in fig. 1.

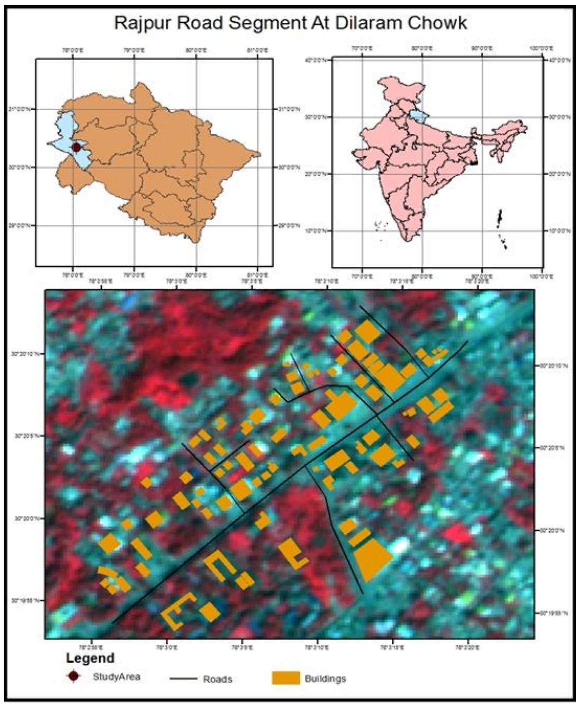

Figure 1: Study area (LISS-IV imagery: 15-Sep-2013)

3. Materials and methods

Traffic noise modelling

There are three important conditions to develop proper mathematical models that are capable of predicting the equivalent and statistical noise levels in a satisfactory manner (Calixto et al., 2003),

- The model should be simple to be used by urban planners;
- The model should require only easily obtained data for the noise level calculation;
- The model should incorporate satisfactory results as per the requirement.

Simple Calculation Method 1 (SCM-1)

The noise computation methods are designed such that traffic noise levels are accurately estimated and these are application for any area for noise simulation. The standard noise calculation methods in the Netherlands are based on extensive measurements done in the year 1970s and 1980s (Schrenk, 2008). These methods are categorized in various groups as per the purpose of the application. In cases where simple scenarios are considered with fewer calculations(Reza Ranjbar et al., 2012).

Standard Calculation Method 1 (SCM1) is generally used for initial assessment of noise impact as the reflections and obstruction of sound between the buildings is not considered in this method. It can be easily implemented for any condition and can have quick result for assessment. The equation used for SCM1 is (Schrenk et al., 2008)

$$SCM1 = E + Cs + Ci + Cr - Dd \text{---------------} \quad (1)$$

where, E is the emission level at source estimated using the traffic flow quantity and other traffic attributes, Cs is the noise correction term applied for the type of road surface, Cj is the correction term applied for any traffic-light controlled junctions, Cr is the correction term applied for any rebound from vertical surface like buildings and noise barriers, Dd is the correction factor applied due to the distance attenuation from the source and De is the correction factor applied due to air attenuation, soil attenuation and meteorological influences.

Standard Calculation Method 2 (SCM2) is a more complex methodology which considers all the factors affecting noise levels. The factors considered also includes reflection and obstruction of sound between buildings which is not considered in SCM1.

Proposed model

Traffic noise modelling was aimed to be robust to calculate the traffic noise emitted by the source measured at the source having a traffic flow of fixed range of velocity. In Indian scenario, consideration of various vehicles types is essential to create an effective Traffic Noise Model. As an account of this condition, a modified version of Calixto model (Calixto et al., 2003) has been proposed (eq (2)),

$$Leq(A) = a * 10 * Log(Qeq) + k \dots\dots\dots\dots\dots\dots (2)$$

$$Qeq = Q(1 + \frac{\Sigma(Ni+Vpi)}{100} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

where, Q is Total quantity of vehicles, Ni is multiplication factor to find equivalent traffic flow such that it accommodates for additional impact of heavy vehicles on overall noise. Qeq is the equivalent total quantity of vehicles, a and k are constant coefficients and Vpi is the percentage of the type of vehicle.

Traffic data collection

For traffic noise modelling, 23 sample points were collected around two of the busiest routes in Dehradun. The first one is Saharanpur road which is a national highway (NH 72A) that connects Dehradun to Saharanpur and the other one is the Rajpur Road that connects Dehradun to Mussoorie which is the mostly preferred tourist place in the region. The location of the sample points collected on these two sites are shown in the figure 2(a) and 2(b). An audio was recorded for each sample point and processed using Virtual Sound Level Meter (VLSM) v0.41 to estimate the A weighted noise level that is Leq (A). The VLSM window along with an output generated after processing one of the sample audio is shown in fig 3.

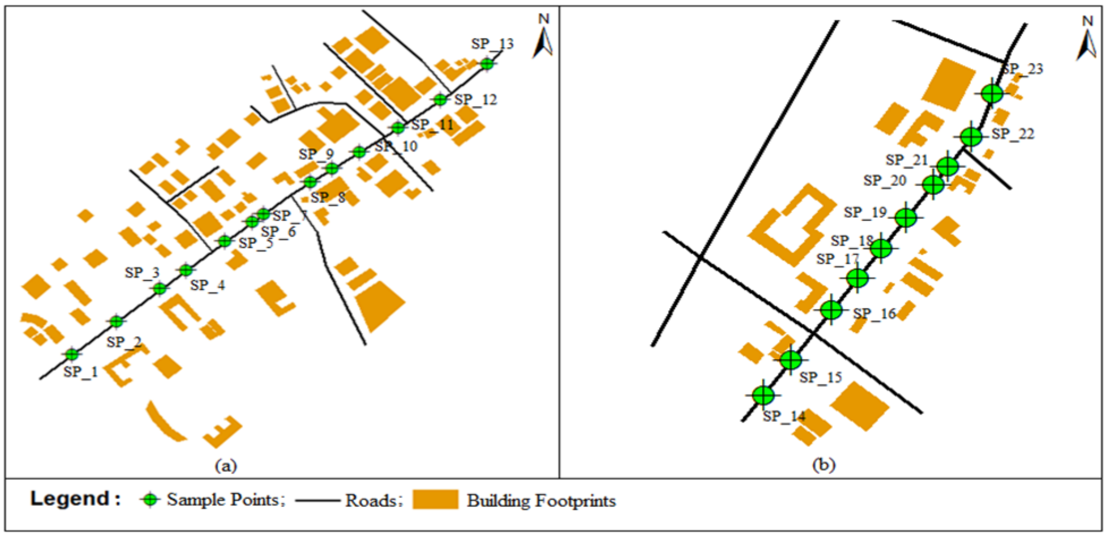

Figure 2: Sample points for traffic noise modelling (a) Site 1 (Rajpur Road); (b) Site 2 (Saharanpur road)

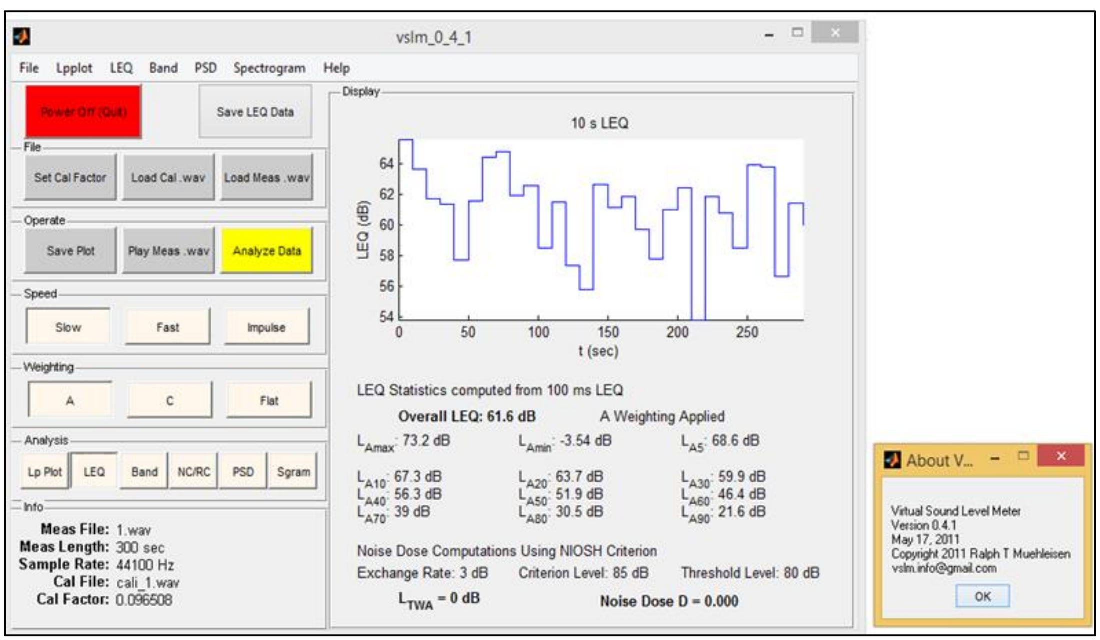

Figure 3: VLSM v0.41 with an output window for one of the sample audio

Table 1: List of sample points used for traffic noise mapping

ID	2W per hour	2W Avg. Speed. (km/h)	3W per hour	3W Avg. Speed. (km/h)	4W per hour	4W Avg. Speed. (km/h)	HV per hour	HV Avg. Speed. (km/h)	Noise Level (Leq (A)) (dB)
SP_1	1344	35.00	156.00	31.00	600.00	46.00	216.00	27.00	76.70
SP_2	1308	46.00	216.00	32.00	648.00	40.00	180.00	28.00	75.90
SP_3	1368	43.00	276.00	36.00	516.00	42.00	84.00	30.00	76.30
SP_4	1392	46.00	252.00	32.00	804.00	47.00	156.00	33.00	76.80
SP_5	1380	43.00	204.00	37.00	1032.00	42.00	168.00	31.00	76.80
SP_6	1416	42.00	240.00	33.00	708.00	50.00	192.00	34.00	77.00
SP_7	1116	45.00	108.00	32.00	732.00	41.00	144.00	32.00	76.30
SP_8	1464	38.00	252.00	30.00	828.00	44.00	168.00	32.00	77.20
SP_9	1344	42.00	324.00	37.00	612.00	36.00	96.00	32.00	75.90
SP_10	1368	35.00	180.00	31.00	648.00	37.00	96.00	35.00	76.40
SP_11	1404	48.00	240.00	30.00	684.00	31.00	168.00	38.00	76.90
SP_12	1164	29.20	300.00	31.00	564.00	34.00	156.00	29.20	75.90
SP_13	924	29.80	288.00	29.40	804.00	36.17	120.00	29.80	75.70
SP_14	1128	34.29	288.00	31.25	696.00	31.25	132.00	34.29	76.20
SP_15	984	34.00	156.00	30.60	792.00	35.20	132.00	34.00	75.60
SP_16	1092	33.60	228.00	33.00	636.00	42.80	180.00	33.60	75.70
SP_17	1260	30.57	192.00	34.50	912.00	41.25	204.00	30.57	77.00
SP_18	1200	29.83	216.00	33.00	624.00	41.17	144.00	29.83	75.80
SP_19	1344	35.80	216.00	39.25	624.00	41.20	144.00	35.80	76.30
SP_20	888	38.00	312.00	35.00	864.00	40.33	228.00	38.00	75.90
SP_21	1056	33.50	240.00	34.80	708.00	40.60	144.00	33.50	76.60
SP_22	1260	38.60	240.00	33.40	672.00	38.25	192.00	38.60	77.00
SP_23	924	36.25	228.00	36.40	684.00	39.25	180.00	36.25	75.80

2W: Two Wheelers (motorbikes, Scooters etc.); 3W: Three Wheelers (Auto Rickshaws, Carriage loaders etc.); 4W: Four Wheelers (Cars, jeeps etc.); HV: Heavy weight Vehicles (trucks, buses etc.

Proposed web architecture

A thick client web architecture has been developed to visualize the 3D models on Cesium Globe for semantic analysis. Cesium supports drawing and layering of high-resolution imagery (maps) from several standard services (Analytics Graphics, Inc. 2011). On top of imagery layer it supports various 3D vector data formats like GeoJason, kml etc. for visualization and analysis. Fig. 4 shows the complete implementation architecture of the developed web GIS framework. The web service call was implemented using Jason objects embedded in a simple XmlHttpRequst protocol.

Web server

The web server serves two purposes,

1. Interaction with Spatial database that is PostGIS (+ 3DCityDB)
2. Conversion of 3D features and other associated attributes to Jason Response Objects.

The main focus of spatial data queries was the efficient retrieval of 3D building features from 3D City Database using the location of object as one of the conditional query attribute. Apart from the geometry of the object, the relative parameters like traffic noise level, building name and year construction of the building were retrieved from the database as per the request from the end. The response expected on the front end is a Jason object so a converter is implemented to transform the data retrieved from database into Jason object. The Jason object were sent back to the web client for visualization and further analysis.

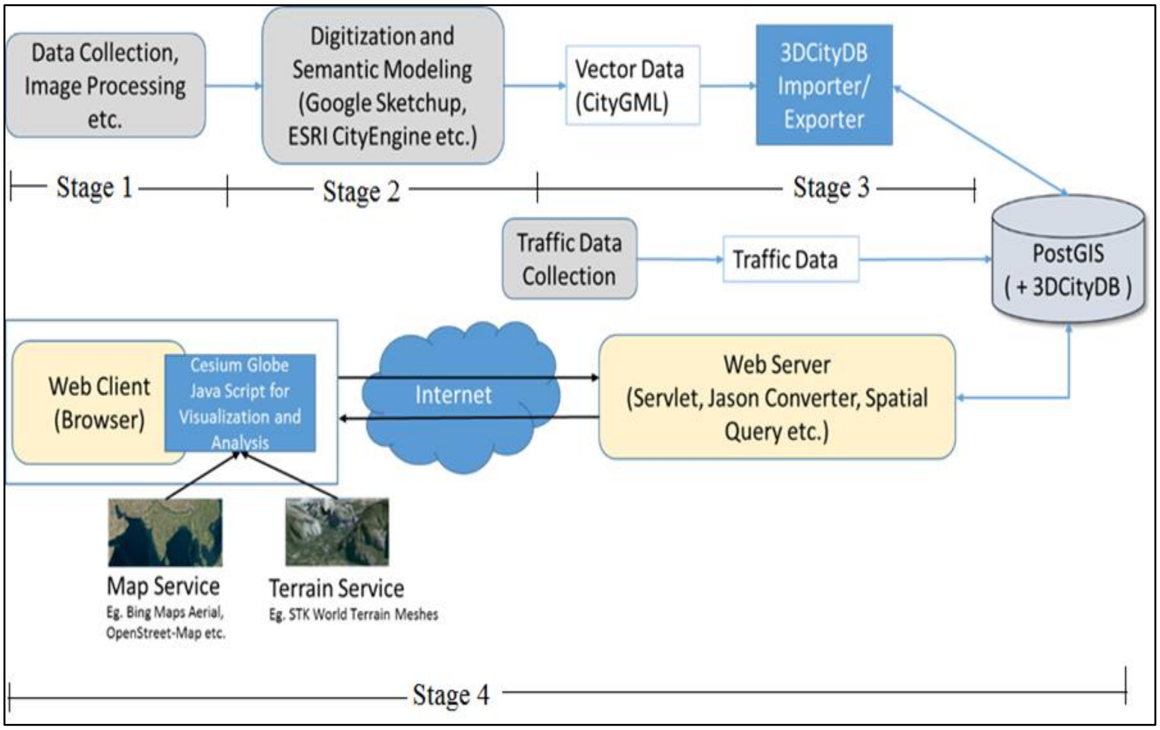

Figure 4: Proposed architecture traffic noise mapping and visualization

Cesium web client

The developed cesium web client supports visualization in two modes, Voxel based 3D visualization and semantic 3D visualization (LoD0, LoD1 and LoD2). The important GIS functions implemented on web client for the analysis and visualization for 3D geospatial information on traffic noise are,

1. Voxel model and semantic model visualization
2. Voxel based spatio-temporal traffic noise mapping
3. Spatio-temporal traffic noise mapping at semantic levels (LoD1 and LoD2)

Distance attenuation

As per the Standard Calculation Method 1 (SCM1) method, the distance of the observation point is one of the important noise reduction factor. So an algorithm was developed to calculate the 3D distance of observation point from the road polyline. The flow diagram of the algorithm is shown in the fig. 5. The algorithm considers two cases to find the distance between the observation point and a line segment as below,

Case 1: The intersection point of the perpendicular from the observation point on the line lies between the end points of the line segment.

In this scenario the distance between the point of intersection and the observation is the minimum distance between the line segment and observation.

Case 2: The intersection point of the perpendicular from the observation point on the line lies beyond the end points of the line segment.

In this case the minimum of the distances between the observation point and each end point of the line segment is the minimum distance between the line segment and the observation point.

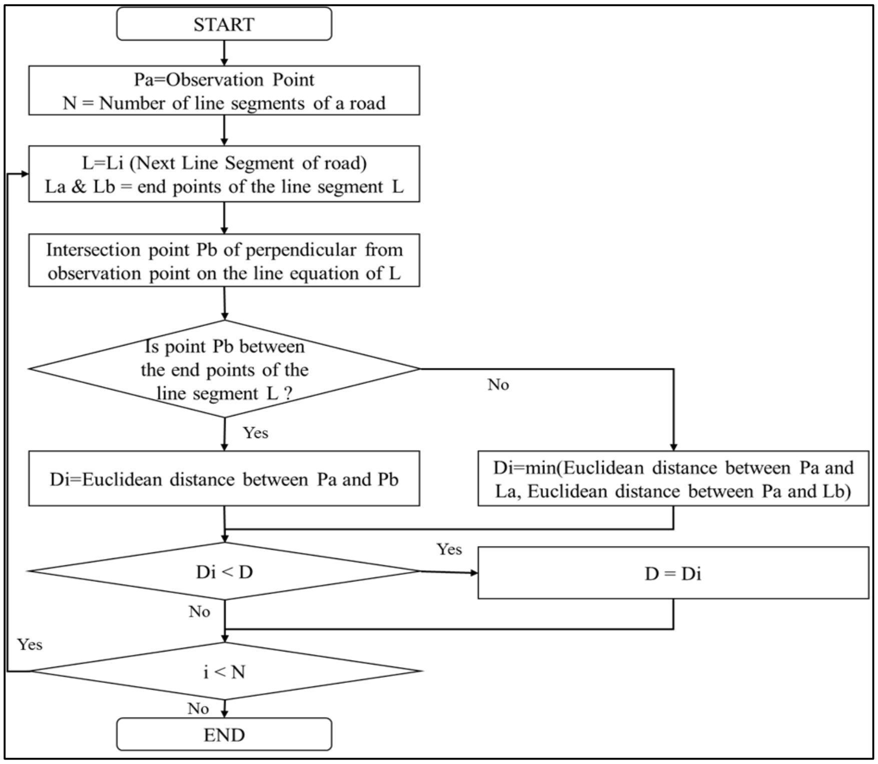

Figure 5: 3D traffic noise mapping algorithm

4. Results and discussion

Traffic noise model

The estimated coefficients estimated after the sensitivity analysis on the proposed traffic noise model, is shown in table 2 below. And the statistical regression model generated and utilized for traffic noise mapping in the study area is,

Laeq =
37.386 + 9.839* log(Q*(1+(3.5* Ptw +0.7* Pthw +1.8* Pfw +6.5* Phv)/Q))/log(10) ……………… (4)

where, Laeq is the equivalent noise level, Q is the total quantity of vehicles, Ptw is the percentage of two wheeler vehicles, Pthw is the percentage of three wheeler vehicles, Pfw is the percentage of four wheeler vehicles and Phv is the percentage of heavy vehicles.

This equation is empirical regression model with logarithmic fitting. The model is derived from the sample points of the road segment. The model is applicable only in Dehradun city. However there may not be much variation because the road conditions are more or less similar.

The model accommodates for the various types of vehicles to match the Indian traffic scenario. An average residual error between predicted noise levels estimated using the developed model and the actual values was estimated to be 0.08 dB. Correlation between actual value and predicted value was found to be 0.72. The root mean square error (RMSE) was estimated to be 0.37 dB.

Table 2: Estimated coefficients for vehicle types

Type of vehicle	Coefficient
Two Wheelers	3.5
Three Wheelers	0.7
Four Wheelers	1.8
Heavy Vehicles	6.5

CityGML and Voxel model visualization

The Jason objects for both LoD1 and LoD2 retrieved at the web client were visualized on the Cesium web globe as shown in fig 6 and 7 respectively, To create 3D traffic Noise Maps, such that the vertical profile of the traffic noise level is mapped on the building walls, it is realistic to create 3D observation points at regular intervals over the area of interest. To perform this task, a Voxel model was generated using the LoD1 block model of the study area and visualized on Cesium Globe as shown in fig 8.

Figure 6: LoD1 model visualized on Cesium Globe

After review and analysis of the rendering and visualization of the LoD1, LoD2 CityGML models and the Voxel based 3D model, it was observed that, the rendering of LoD1 and LoD2 models that are the semantic models is faster as compared to the rendering of Voxel based models. As we decrease the size of a Voxel the rendering tends to be slower showing reduced performance.

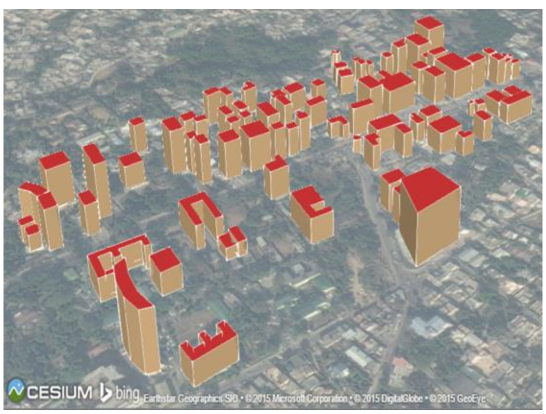

Figure 7: LoD2 model visualized on Cesium Globe

Figure 8: Voxel model visualized on Cesium Globe

Voxels based spatio-temporal traffic noise mapping

In the Voxels based approach, the center of each grid cell on the wall surface was considered as the observation point and its 3D Euclidian distance was calculated from the road polyline using the algorithm developed. This distance was applied as a noise reduction factor. A 3D traffic noise map (7 p.m.), generated as a result of this approach is shown in fig 9. Cesium is also equipped with function for temporal visualization of geospatial information. This feature of cesium was utilized to create an animation for the temporal variation in traffic noise level. The graph in fig. 10 represents this temporal variation.

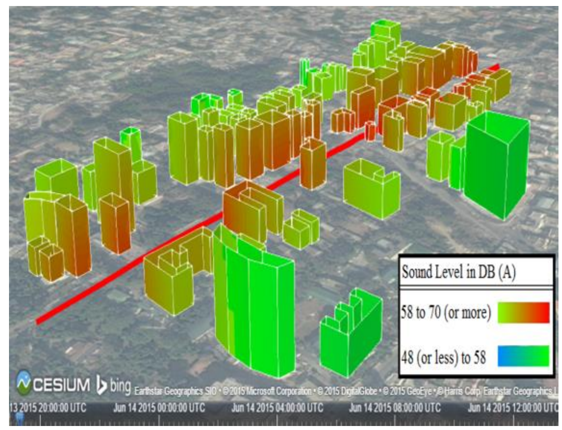

Figure 9: 3D traffic noise map (7 P.M.) using Voxel model of the study area

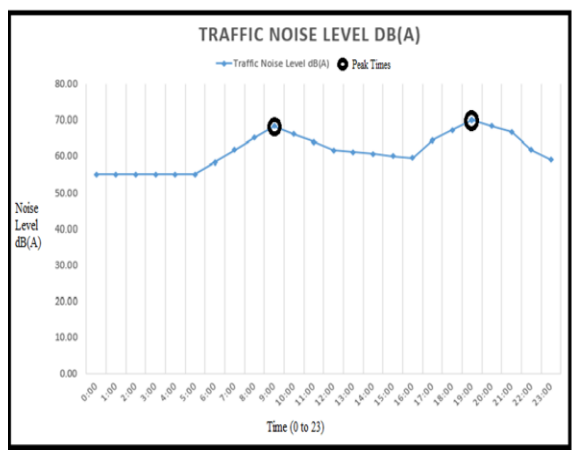

Figure 10: Temporal variation of the traffic noise at 10 m distance from the road center

From the time graph it can be easily depicted that the noise level is highest during 9:00 am in the morning and in the evening at 7:00 pm. The maximum noise level observed in this case was around 75 dB (A) at a distance of 10 m from the road center. The traffic noise map generated using Voxel based model is more detailed and truly 3D in nature. It is capable of mapping the noise levels at all observation points at regular intervals.

CityGML based spatio-temporal semantic analysis

The LoD2 CityGML model was used to map the traffic noise on the surface features of the buildings like wall surface, roof surface. The map generated as a result was rendered on the Cesium Globe. The result is shown in figure 11.

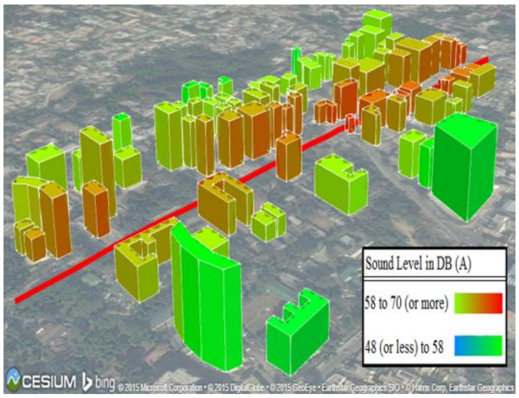

Figure 11: Traffic noise map generated using the LoD2 CityGML semantic model

The traffic noise maps generated using this approach are rendered on web browser very fast. The traffic noise levels are mapped at the feature level so, there is only one value of noise level associated with each feature like a wall surface.

Spatio-semantic analysis

As per the depiction from the time graph, the traffic noise level at 7:00 pm were highest. So, the noise levels at 7 p.m. were used to perform the spatio semantic analysis. A review on the European southern and northern region by (Diaz et al., 2001) depicts the harmful effects of noise on health of people. After carefully reading this document a decision was made to perform the semantic analysis to quantify the effects in terms of the number of building surfaces exposed to 65 dB (A) or more. For this, a semantic query was applied on the LoD2 model to retrieve and highlight the building surfaces exposed to 65 dB (A) or more. The result of semantic query is shown in the fig 12.

The number of wall surfaces and roof surfaces exposed to the threshold level of 65 dB or more were 54 and 6 in number respectively. From this it can be depicted that a considerable number of people leaving in the vicinity of highway or the heavy traffic road are affected by the high level of traffic noise which can result in adverse effects on the health of people leaving in the area. From the semantic query applied, it can be easily identified that some of the buildings has the above threshold noise level impact only on the surfaces that face towards the road. A design decision can be taken by architects and urban planners to avoid the bedrooms, balconies or in some cases the windows towards the roadside. Also, for an under construction site, an architect or a planner can apply certain modifications to the site design such that, the resulting model will have lesser impact on the overall site or the susceptible areas of the site.

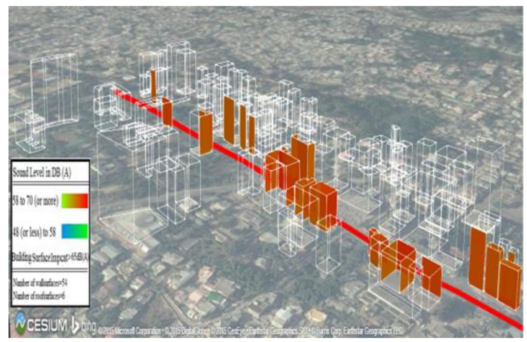

Figure 12: Semantic query for building surface with noise impact >= 65dB (A)

Spatio-temporal semantic analysis

The spatio temporal analysis was performed to estimate the number of roof surfaces and the number of wall surfaces affected with 65 dB (A) or more from the start to the end of the day. The graph in fig 13 shows this variation. It can be observed that these numbers are highest at around 7:00 pm in the evening and 9:00 am in the morning.

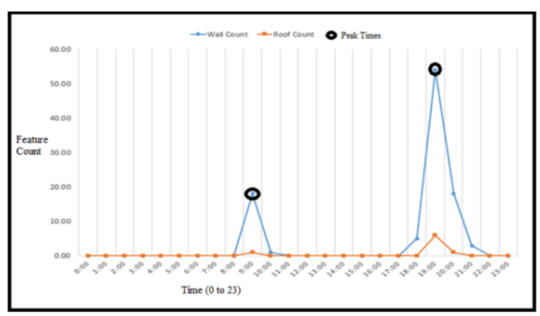

Figure 13: Number of walls and roofs affected from start to the end of the day

Voxel based traffic noise map vs. LoD2 traffic noise maps

The traffic noise maps generated using the two approaches were compared for efficiency and utilization. The results of comparison are listed in the Table 3.

Table 3: Voxel based traffic noise map Vs LoD2 traffic noise maps

Characteristics	Voxel based TNM	LoD2 TNM (CityGML)
1. Web Rendering Speed	√	√√
2. Semantic Analysis	×	√
3. Traffic Noise Mapping	**At grid level**	**At semantic level**
4. Interoperable	×	√
5. Planning and Design Perspective	**Indirect & Less useful**	**Direct & More useful**

5. Conclusion and recommendations

The research work was a successful attempt to apply spatio semantic approach for the analysis of 3D urban features using the OGC encoding standards. The developed application can be utilized for the semantic analysis of the urban features to take pre and post construction design and mitigation decisions. A simple traffic noise model was developed that could be applied to the Indian traffic scenario. The developed model was successfully transformed into an interoperable data encoding standard that is CityGML, supported by OGC and also into a Voxel-grid model to analyze sudden spatial variations in traffic noise level. An enterprise application was proposed and implemented to support the geospatial analysis on web. The implemented web GIS architecture was also successfully extended to support the visualization and semantic analysis of urban features and their thematic attributes like traffic noise emission level and all the inputs and outputs of SCM-1. It is also capable of simulating the spatio-temporal variation of traffic noise in the virtual environment from the start to the end of the day. Additionally, spatio-temporal semantic analysis was performed successfully to identify the peak times when the traffic noise level is highest during the day and also to identify the number of roofs and walls that are affected the most. A comparative analysis for Voxel based and CityGML based approach was performed and it was observed that, as the traffic noise levels vary logarithmically, and planners intend to know the effects of the traffic noise levels at semantic levels to take certain design decisions, the CityGML based semantic approach is more efficient and practical. With the open source or freely available technology utilized at every step of this research work, it can be concluded that the research work has presented a cost effective web based GIS solution for 3D traffic noise mapping and semantic analysis of traffic noise impacts.

Recommendations

- ✓ LoD3 and LoD4 models of the buildings can be reconstructed and analyzed semantically. A semantic analysis of LoD4 models can depict the actual effect of traffic noise on people living inside the building.
- ✓ Other urban features like Pavements, Footpaths, Gardens and Public Places like Railway stations can be analyzed semantically for mapping the noise more accurately. More tools can be added to the GIS framework for analyzing the effects of preventive measures like a noise barrier between the road and residential area.
- ✓ A traffic noise model based on SCM-2 methodology can be developed for an accurate measurement of noise levels. And also a CityGML ADE schema for the interoperability of the attributes of SCM-2 can be proposed.

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