

Urban Noise Mapping using 3D-GIS

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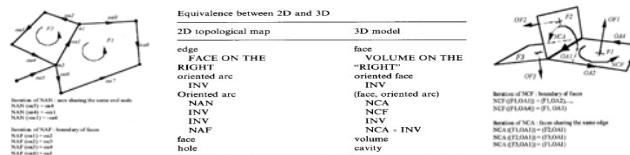
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- 3D-GIS Data Modeling for Urban Noise Mapping
- Noise Data Acquisition and Storage
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Background

- With increase of urban noise, urban planning and design use noise maps increasingly.
- 3D noise maps are also paid attention increasingly.
- Existing studies about 2D and 2.5D noise maps show limitations in visualizing and analyzing noise level at fine scale.
- We suggest 3D GIS data model for 3D noise mapping by extending 2D topology to 3D.
- We show process to develop an application and apply to 3D noise analysis.

Related Studies

- Losa(1999) : mathematical study on 3D topology
 - Extended 2D topological relationship to 3D



- Defined 9 intersections between two objects, A and B.

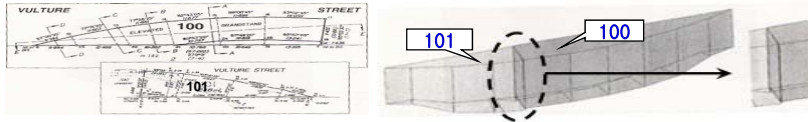
$$(\partial A \cap \partial B, \overset{\circ}{A} \cap \overset{\circ}{B}, \overset{\circ}{A} \cap \partial B, \partial A \cap \overset{\circ}{B}, \bar{A} \cap \bar{B}) \quad \begin{array}{l} \partial A: \text{boundary of } A \\ \overset{\circ}{A}: \text{interior of } A \\ \bar{A}: \text{complementary of } A \end{array}$$

$$\partial A \cap \bar{B}, \overset{\circ}{A} \cap \bar{B}, \bar{A} \cap \partial B, \bar{A} \cap \overset{\circ}{B})$$

- This study partly employed Losa's idea.
 - Implemented 3D topology using the intersection between walls(∂A) and volumes($\overset{\circ}{A}$).

Related Studies

- Stoter(2005) : 3D topology for cadastral data
 - Stored 3D cadastral geometries and topology in a DB.



- 3D queries for the adjacent objects.

```
/*check if two geometries intersect (1=TRUE and 0=FALSE)*/  
SELECT d1.bid, d2.bid FROM robject3dql d1, robject3dql d2  
WHERE intersection(return_polyhedron(d1.shape), return_polyhedron(d2.shape), 0.01) = 1  
AND d1.bid < d2.bid;
```

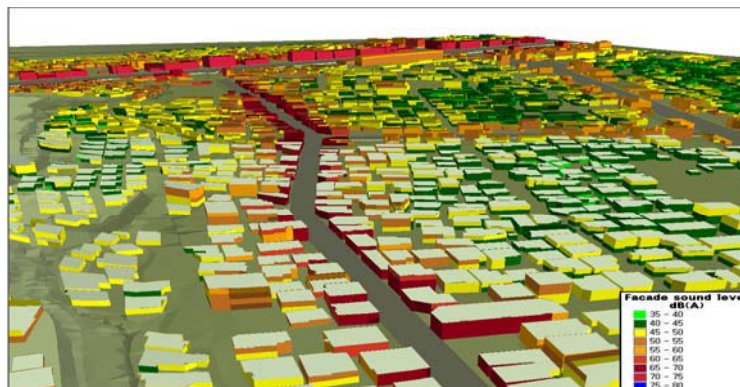
```
BID BID  
100 101
```

Two faces are defined to have adjacency
when they are within certain distance

- We used Stoter's idea on discretizing volumes in building 3D topology.
 - Made adjacent volumes share walls.

Related Studies

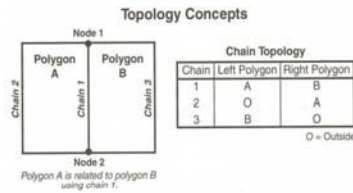
- Koh(2006), Jang(2005), etc. : 3D noise mapping
 - Actually these maps are 2.5D.
 - Cannot display different noise levels for different room units.



Topology

■ Topology

- Relationship of figures that remain unchanged even if figure is bent or stretched
- Central concept of GIS that allows geographic operations



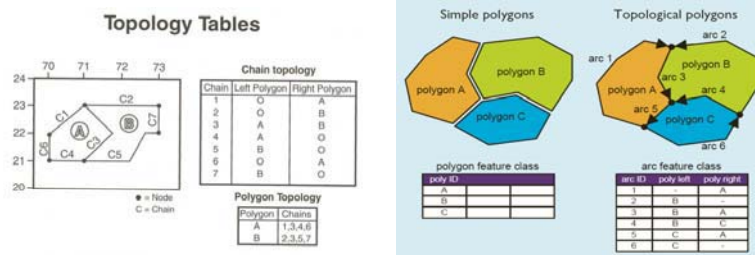
■ Use of topology

- Identify objects that are adjacent or connected to other objects
- Relationship of network
- Make spatial analyses possible

Topology

■ Topology Table

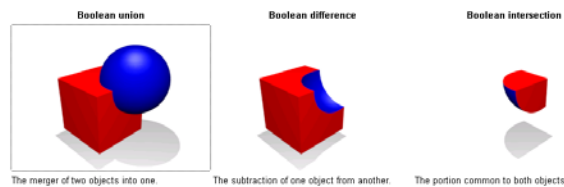
- Stores relationship between objects (connectivity and adjacency)



- We need similar table structure in 3D topology

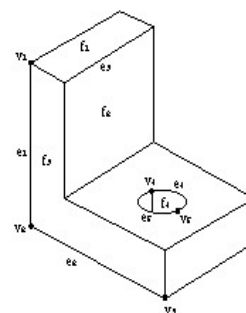
Geometric Object Modeling(CSG)

- Two popular 3D object modeling techniques : **CSG** & **B-rep**
- CSG (Constructive Solid Geometry)
 - Objects are constructed from primitives by means of Boolean operations on sets (*i.e.* union, intersection and difference)
 - CSG do not consider topological relationships between objects



Geometric Object Modeling(B-rep)

- B-rep (Boundary Representation)
 - Represents relationship how faces, edges and points are connected.
 - B-rep is more flexible and has a much richer operation sets than CSG
 - Topology
 - Stores connectivity among surfaces, edges and points.
 - Geometry
 - Stores shape and location of components (surfaces, edges and points)

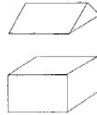


Geometric Object Modeling

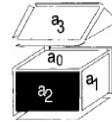
■ Simple vs. CSG vs. B-rep model



simple solid model



CSG model



B-rep model

■ We used B-rep in this study

- defined relationship between volumes and faces(walls)
- constructed a 3D object by faces that surround each volume

Overview of Proposed Method

■ 3D-GIS Data Modeling for Urban Noise Mapping

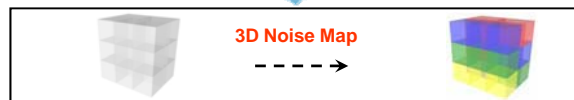
Existing noise maps → 2D / Regional units
Buildings become complex → Demand 3D / finer scale mapping

Data Structure
Face & Volume

- Visualize noise data projected to wall units
- Spatial query and visualization

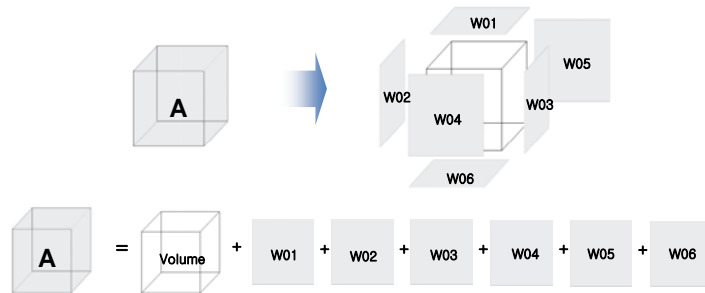
Data Model
Relational DB

- Relationship of walls & volumes → 3D Topology
- Volume & Sub Volumes → fine scale analysis



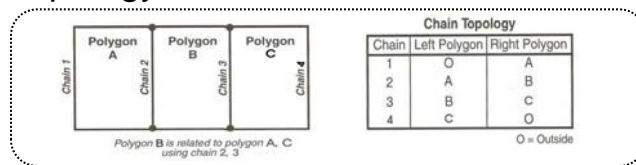
Data Structure: Faces & Volumes

- For Visualization of noise data projected to building walls, we defined a building using a volume and its walls.
- Extended concept of 2D Topology to 3D

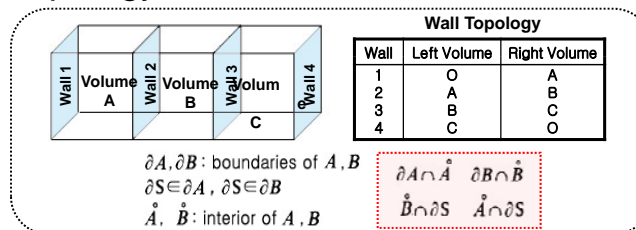


2D & 3D Topology

2D Topology

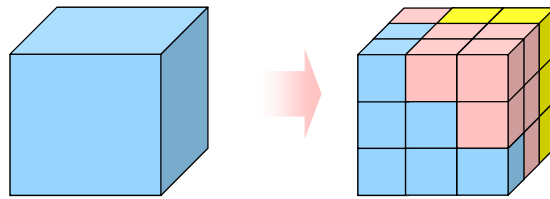


3D Topology

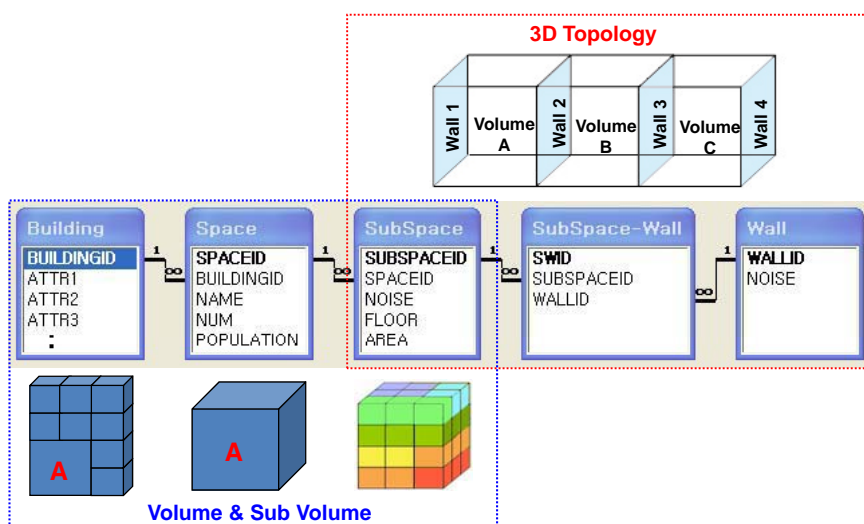


Volume & Sub Volumes

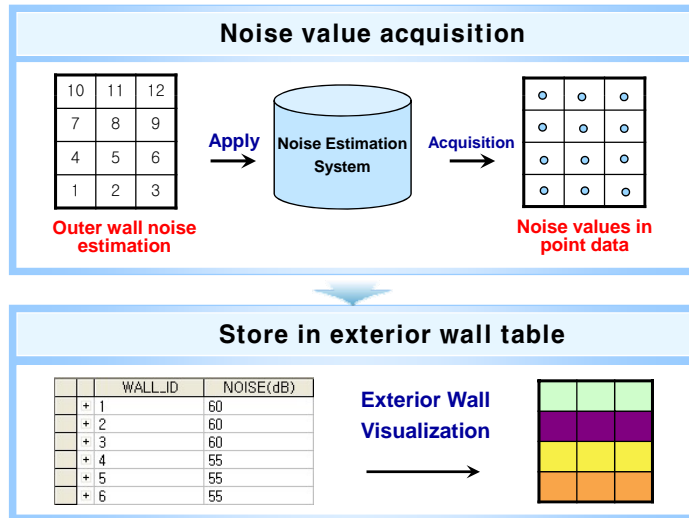
- Large spaces such as theater or lecture halls are too big for having one representative noise level.
- In such cases, we divided a volume into sub spaces.



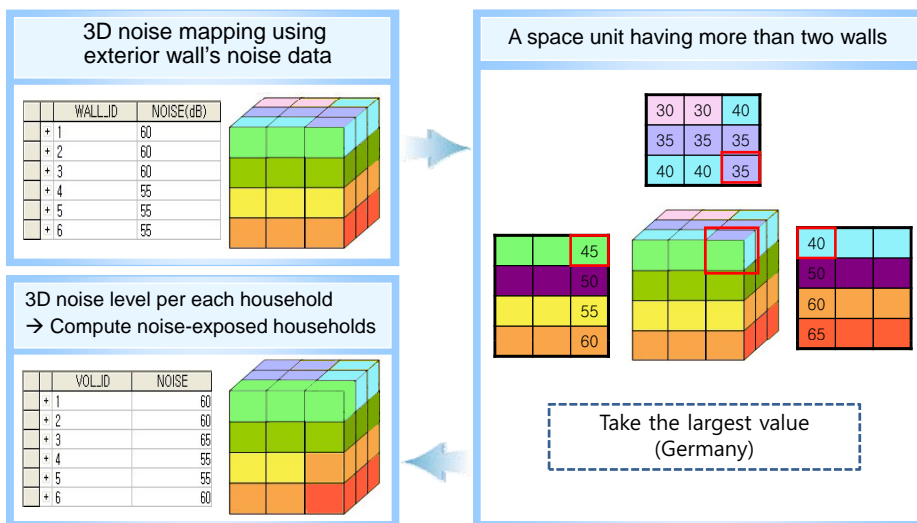
Database Modeling – Relational DB



Noise Data Acquisition and Storage



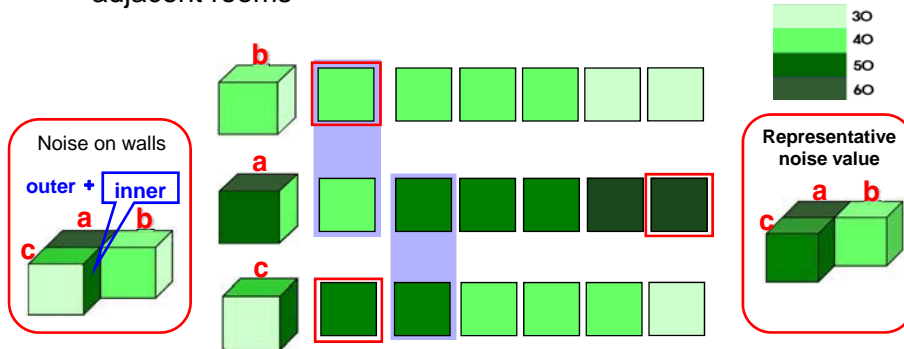
Noise Data Acquisition and Storage



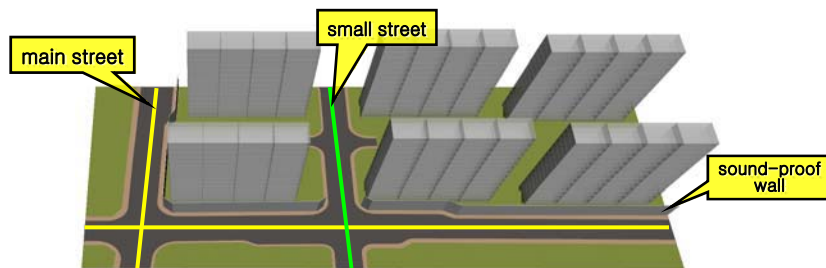
Noise Data Acquisition and Storage

Proposed 3D Data Model

- It is possible to visualize noise values at wall levels composing a space
- 3D topological structure helps analyzing noise impacts of adjacent rooms



System Test



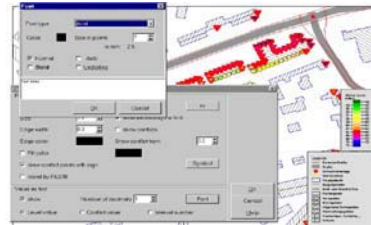
Apartment complex	
Apt. bldgs.	15 story-bldgs.
Streets	Main streets, small roads
Sound-proof walls	
Height	4 m
	8 m

Rush hour (05:00-08:00, 18:00-22:00)	Flow	6000 veh/hr	1000 veh/hr
	Speed	50 km/hr	40 km/hr
Day time (08:00-18:00)	Flow	3000 veh/hr	400 veh/hr
	Speed	70 km/hr	40 km/hr
Night time (22:00-05:00)	Flow	500 veh/hr	100 veh/hr
	Speed	80 km/hr	40km/hr

Noise Estimation System

SoundPlan

- Popularly used noise estimation system
- Use different formulas by noise sources
- Street traffic noise
 - RLS90 DINI8005(Germany)
 - Point-souece estimation
 - Vehicle flow, speed, surface material, slope
 - obstacles(sound-proof walls), weather impacts



Data types

	A	B	C	D	E	F	G
1	Coordinates			Floor	Name	Noise(dB)	WallID
2	X	Y	Z				
3	95460,36	-36166,989	2,4	1	1번건물	64	W101004
4	95460,36	-36166,989	5,4	2	1번건물	66	W101025
5	95460,36	-36166,989	8,4	3	1번건물	66	W101042
6	95460,36	-36166,989	11,4	4	1번건물	66	W101059
7	95460,36	-36166,989	14,4	5	1번건물	66	W101076

	WALLID	NOISE
+	W101001	63
+	W101002	62
+	W101003	67
+	W101004	64
+	W101005	67

System Features

Spatial query

- Search a space and neighboring spaces using 3D topology
- Spatial query by attribute data (*i.e.* noise levels)

3D noise simulation by

- time -- traffic volume and velocity
- heights of sound-proof wall

Noise impact on households

- Compute population exposed to noise

Concluding Remarks

- Existing 2D noise maps are 2D or 2.5D and have limitations in analyzing at individual room level.
- We proposed 3D data model for visualization and analysis of vertical noise distribution in a building.
- Composed a building with a volume and faces using 3D topological concept.
- Simulated noise variation by time zones and heights of sound-proof walls.
- Proposed method is now being expanded to general-purpose 3D GIS.