Urban Noise Mapping using 3D-GIS

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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.

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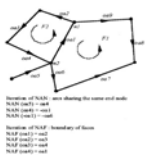
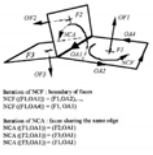
Related Studies

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



Equivalence between 2D and 3D

2D topological map	3D model
edge	face
FACE ON THE RIGHT	VOLUME ON THE "RIGHT"
oriented arc	oriented face
INV	INV
Oriented arc	(face, oriented arc)
NAN	NCA
INV	NCF
INV	INV
NAF	NCA + INV
face	volume
hole	cavity



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

$(\partial A \cap \partial B, \mathring{A} \cap \mathring{B}, \mathring{A} \cap \partial B, \partial A \cap \mathring{B}, \bar{A} \cap \bar{B}$

$\partial A \cap \bar{B}, \mathring{A} \cap \bar{B}, \bar{A} \cap \partial B, \bar{A} \cap \mathring{B})$

∂A: boundary of A

$\mathring{A}$: interior of A

$\bar{A}$: complementary of A

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

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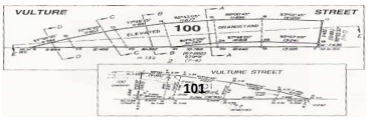
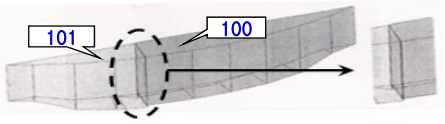
Related Studies

- 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.

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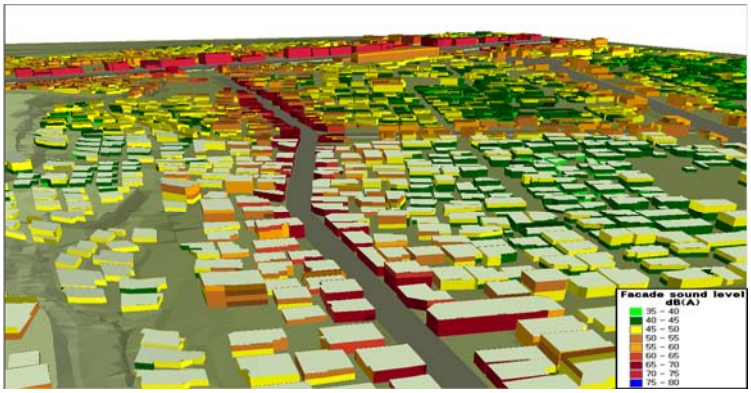
Related Studies

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



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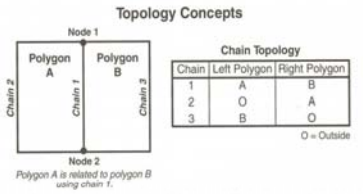
Topology

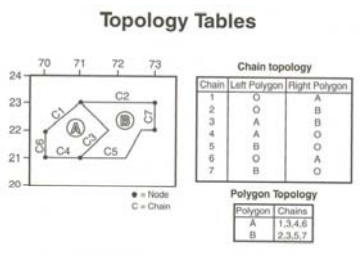
- Topology
  - Relationship of figures that remain unchanged even if figure is bent or stretched
  - Central concept of GIS that allows geographic operations

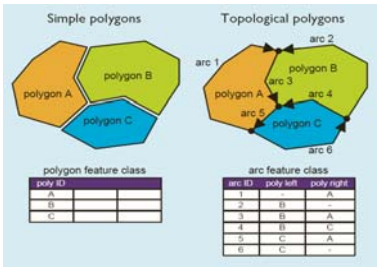


- Use of topology
  - Identify objects that are adjacent or connected to other objects
  - Relationship of network
  - Make spatial analyses possible

Topology

- Topology Table
  - Stores relationship between objects (connectivity and adjacency)



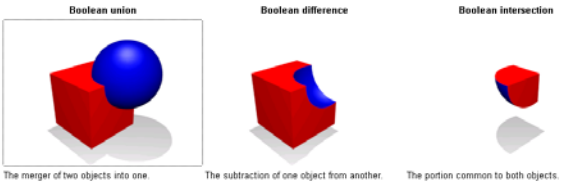


- We need similar table structure in 3D topology

Geometric Object Modeling(CSG)

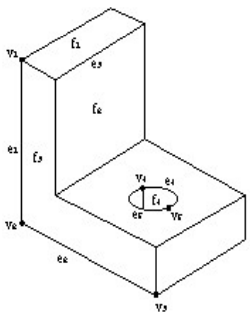
- Two popular 3D object modeling techniques : ***CSG*** & ***B-rep***

- 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



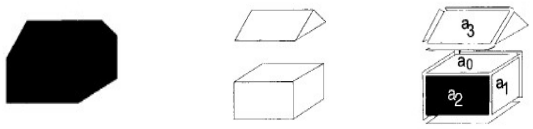
Geometric Object Modeling(B-rep)

- 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

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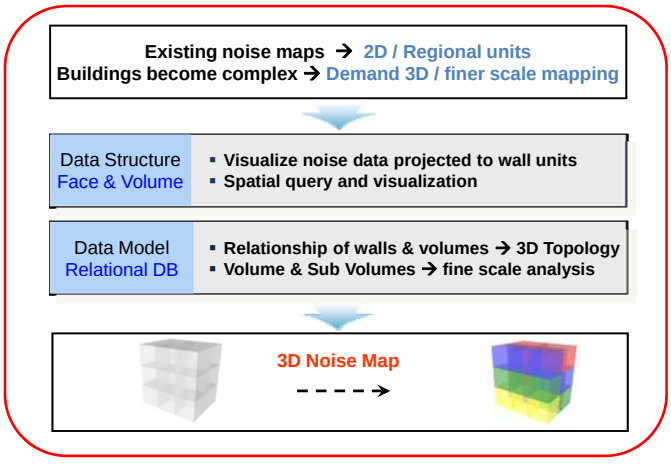
Overview of Proposed Method

- 3D-GIS Data Modeling for Urban Noise Mapping



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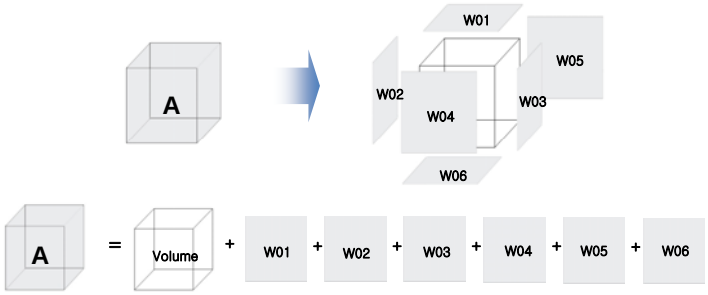
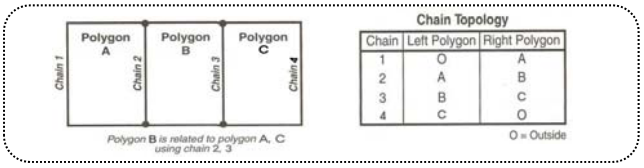
Data Structure: Faces & Volumes

- 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

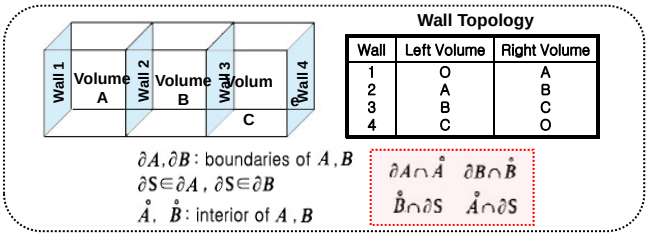


2D & 3D Topology

- 2D Topology

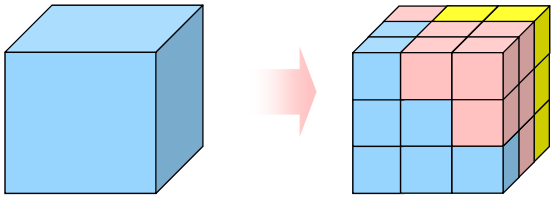


- 3D Topology

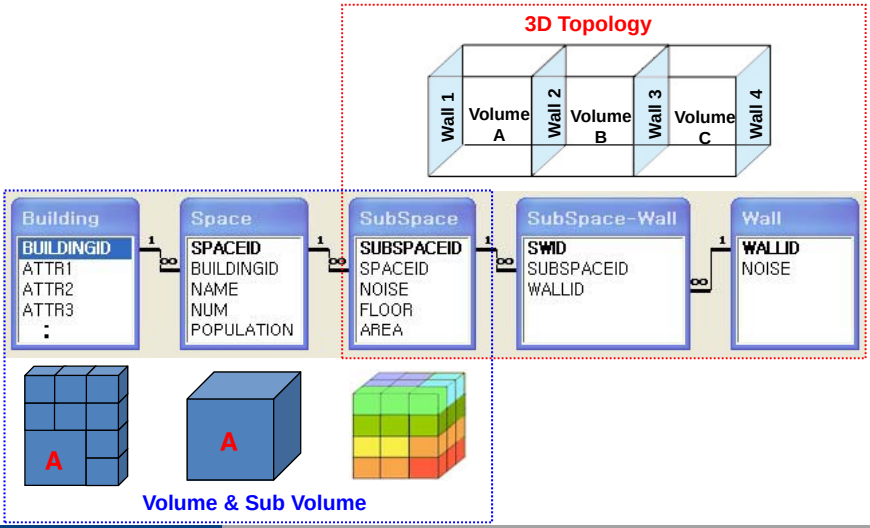


Volume & Sub Volumes

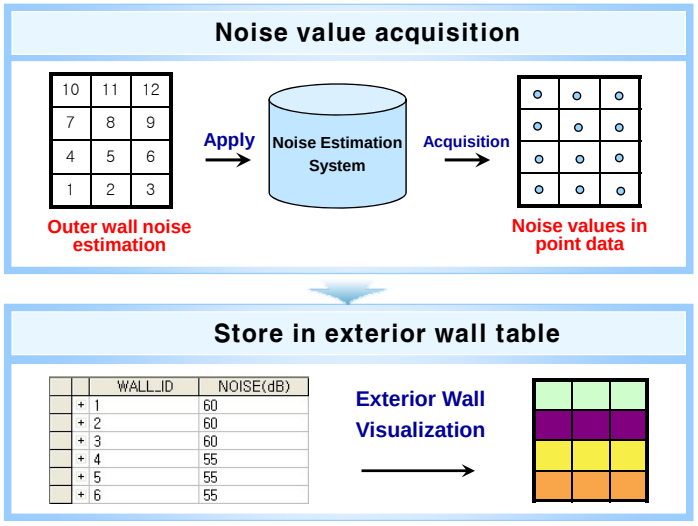
- Large spaces such as theater or lecture halls are too big for having one representative noise level.
- In such cases, we divided a volume into sub spaces.



Database Modeling – Relational DB



Noise Data Acquisition and Storage



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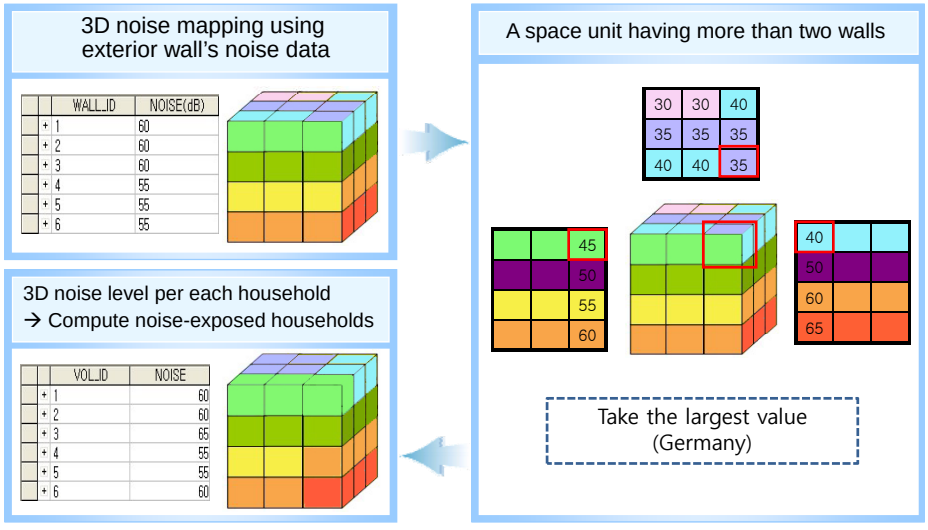
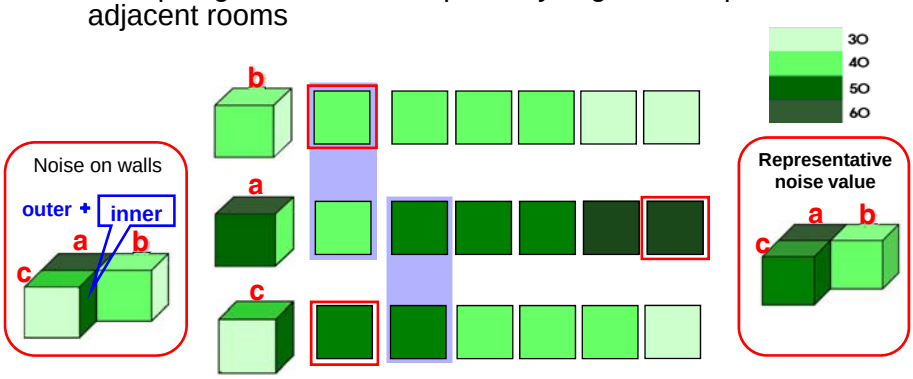
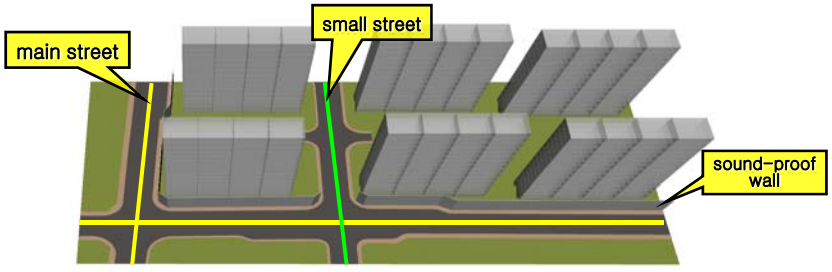


Noise Data Acquisition and Storage

- 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



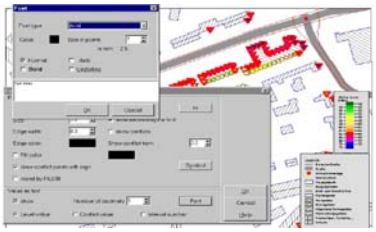
Apartment complex	
Apt. bldgs.	15 story-bldgs.
Streets	Main streets. small roads

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

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.