Development of Structure-based Topology of 3D Spatial Databases for Storing and Querying 3D Cadastre Cases

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Key words: topology, database, cadastre, spatial analyses

SUMMARY

In realizing 3D representation of 3D cadastre objects, the construction of 3D spatial databases requires a special attention. There are two approaches for building 3D database structures to represent 3D spatial objects, namely the geometry and topology-based structure database. The fundamental difference between the two structures is on their storage methods. The storage of spatial data with topology structures does not contain redundant objects. Therefore topological structure offers better data consistency. Meanwhile, geometry-based structure offers practicality in terms of data conversion. In this research, 3D database structure construction was developed using the application that enables topological structures on 3D spatial database with 2.5D approach. The implementation was done using PostgreSQL with PostGIS extension. The resulting data are used to solve 3D Cadastre cases by using spatial analysis tools in Geographic Information Systems (GIS) software. The resulting database was tested using queries that relevant to represent real world's 3D Cadastre cases. The analysis showed that the database with topology-based structure was able to solve some cases of 3D Cadastre that included the neighborhood relationship of the objects.

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1. INTRODUCTION

Rapid developments of residential and business places in already crowded urban areas speed up the rise of new vertical buildings and infrastructures in big cities in many countries.For this reason, many countries initiate new regulations and laws related to 3D property management. Government of Indonesia for example, has anticipated such developments by unleashing the law on Appartment in 2011, replacing the previous law on appartments launched in 1985. It covers policy and regulations on the use and ownerships of appartment units. The authorizatiom, ownership, use and utilization of 3D properties need to be registered. Ideally, the registration should be integrated with the current land registration that is commonly based on 2D maps and data. In Indonesia, the 3D object properties that are mandated to be registered are ownerships at apartement units.

According to Stoter and Oosterom (2006) 3D Cadaster is a cadaster system that is able to do registration and determination of the ownership rights, with the restrictions, not only based on land parcels but also based on space property units that are represented as 3 dimension coordinates and orientation. In the 3D cadaster, the presentation is an important aspect. This is related with the representation of the real condition of the objects completely depicting land parcel status and adjacent rights that are embedded above or under the property.

In realizing 3D representation of 3D cadastre objects, the construction of 3D spatial databases requires a special attention. There are two approaches for building 3D database structures to represent 3D spatial objects, namely the geometry and topology-based database structure. 3D database structure construction can be developed using the application that enable*s* topological structures on 3D spatial database with 2.5D approach.

This paper is aimed to contribute in giving analyses on the use of topology-based spatial database with 2.5 approach using OpenSource database software. For this purpose, PostgreSQL with PostGIS extension version 2.0 was used. The results can be used to decide whether the management of 3D object properties can be sufficiently supported by existing opensource database techonolgy.

2. METHODS

The 3D models of the Simpanglima Building in Semarang were built based on 3D coordinates (X, Y, Z) in UTM reference coordinate system. The data is processed from field measurement utilising field survey instruments namely *Total Station* (TS) *Leica reflectorless TCR805* in 2011. The data then were processed in order to develop 3D models in CAD format.

The development of three dimensional spatial databases include the acquisition of spatial data and attribute data into databases. Spatial data derived from 3D models in CAD format of Simpanglima Building in the city of Semarang. Objects used in the study are the room objects of the first floor of the building and its land parcels' boundaries. Object modeling was done by editing the previous model 3 dimensional with wireframe modeling view. Wireframe modeling is done by using the drawing menu `POLYLINE` and `3DPOLYLINE` in AutoCAD Map 3D 2011.

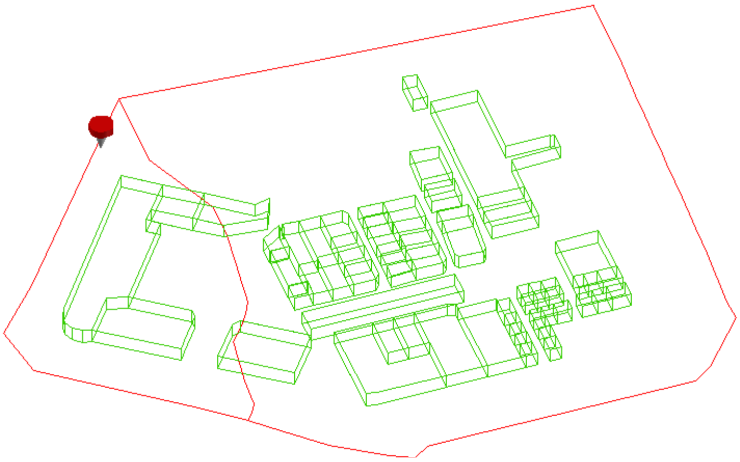


Figure 1. Wireframe view of object models

Once 3D models in CAD format were produced, data conversion from CAD to KML (*Keyhole Markup Language*) was done in order to easily convert the data into geometries stored in spatial databases. Coordinate data or spatial data that make up the 3D models of room objects and boundaries of land parcels were stored in KML format. Data conversion from CAD format into KML was done using Google Earth Extension. Further, spatial data in KML format was converted into PostgreSQL using FWTools 2.4.7 software.

Next step that was done was the construction of topology-based data structure in the database. As of this research was done, the PostGIS 2.0.1 software was only able to build the 2.5-dimension topological approach, hence support for full 3-dimension topological approach involving volume representation was not available. The 2.5 dimension topological approach refers to a representation of coordinates in a 2D plane (X,Y) in which the Z value of each coodinates area also stored in the coordinates. The diagram that describes the construction of a spatial database with topology-based structure is shown in Figure 2.

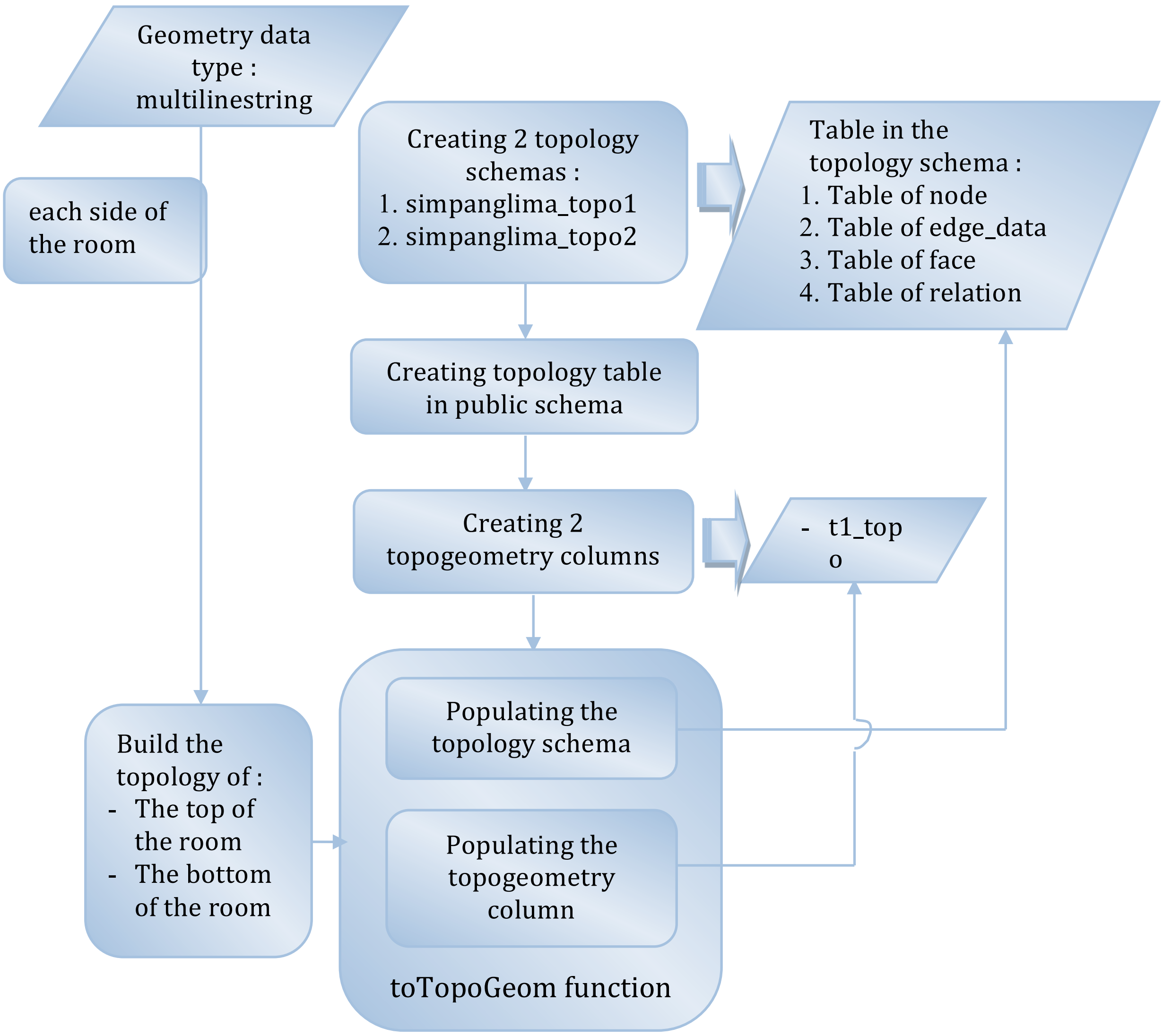


Figure 2. Process Development of the Topology Structure

Based on Figure 2, the development of structure-based topology gets started by creating the topology schemas, that is `simpanglima_topo1` for the top of the room and `simpanglima_topo2` for the base of the room. For each topology schema, there are four tables in the schema, include table of `node`, table of `edge_data`, table of `face` and table of `relation`. This tables are used to stored the geometry data that build the topology structure. The geometry data were automatically stored in the tables when executed the `toTopoGeom` function.

The next step is to create a topology table in the public shema. In this table, two topogeometry columns were created (`t1_topo` and `t2_topo`). In this topogeometry columns, the objects that were build based on topology structure, that called topogeometry, were stored. This columns were also automatically populated when the `toTopoGeom` function was executed.

In processing the topology construction, we assigned the multilinestringz as the geometry type for our input data. The topology of the top of the room uses the geometry data of the top side of the room as input into this topology schema (simpanglima_topo1). Subsequently, the geometry data of the bottom side of the room was also used as input to build the topology of the bottom of the room into this topology schema (simpanglima_topo2).

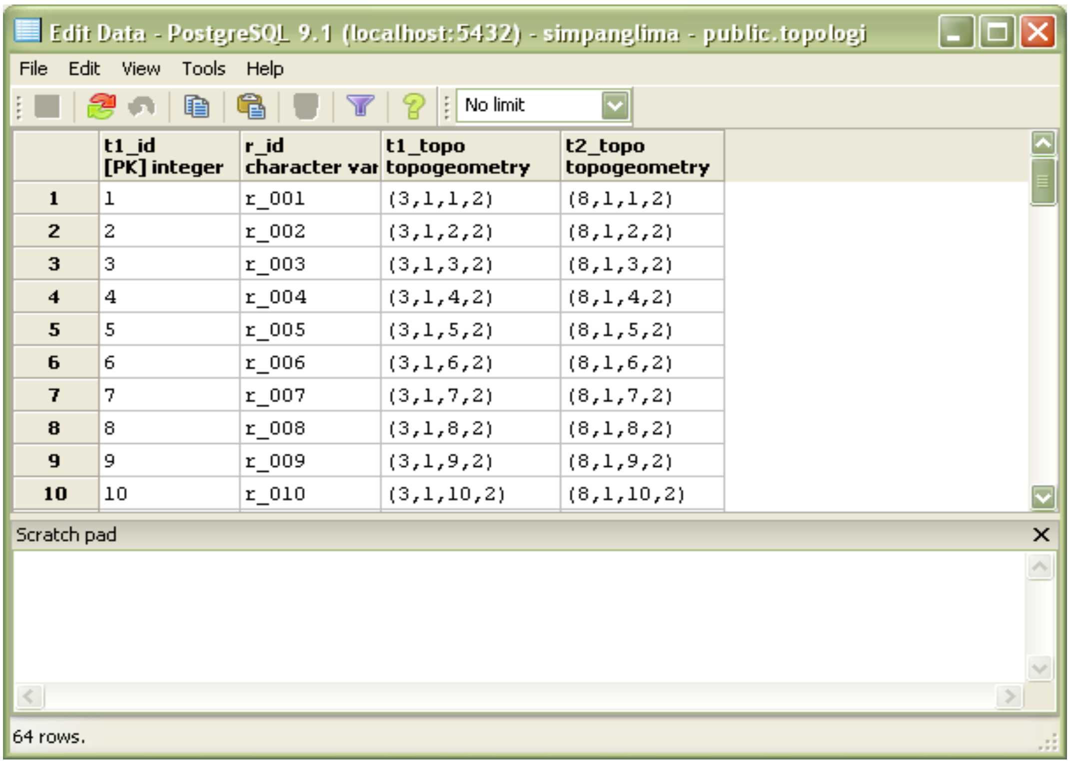
This development process uses the toTopoGeom function that is available through the extension PostGIS 2.0.1. The input data, the top of the room, were then automatically populating into the simpanglima_topo1 schema (table of node, edge_data, face and relation) and into topology table (t1_topo column). The bottom of the room data were populating into the simpanglima_topo2 schema (table of node, edge_data, face and relation) and into topology table (t2_topo column).

The database of the topology structure was tested by using query analysis of topology operations reflecting possible cases in investigating 3D Cadastre data. Analysis of the topology operations was composed as spatial operations namely: equals, disjoint, intersects, touches, crosses, within, contains, and overlaps.

3. RESULTS

3.1 3D Spatial Database of Topology Structure

The databases resulted from this study is a 3-dimensional spatial database of topology-based structure. This database of topology-based structure is not based on solid objects. Topological structures are constructed using 2.5-dimensional approach, which means that the topology was done on a 2D plane on which each pairing X,Y coordinates of objects has a Z value .



Edit Data - PostgreSQL 9.1 (localhost:5432) - simpanglima - public.topologi

	t1_id [PK] integer	r_id character var	t1_topo topogeometry	t2_topo topogeometry
1	1	r_001	(3,1,1,2)	(8,1,1,2)
2	2	r_002	(3,1,2,2)	(8,1,2,2)
3	3	r_003	(3,1,3,2)	(8,1,3,2)
4	4	r_004	(3,1,4,2)	(8,1,4,2)
5	5	r_005	(3,1,5,2)	(8,1,5,2)
6	6	r_006	(3,1,6,2)	(8,1,6,2)
7	7	r_007	(3,1,7,2)	(8,1,7,2)
8	8	r_008	(3,1,8,2)	(8,1,8,2)
9	9	r_009	(3,1,9,2)	(8,1,9,2)
10	10	r_010	(3,1,10,2)	(8,1,10,2)

Scratch pad

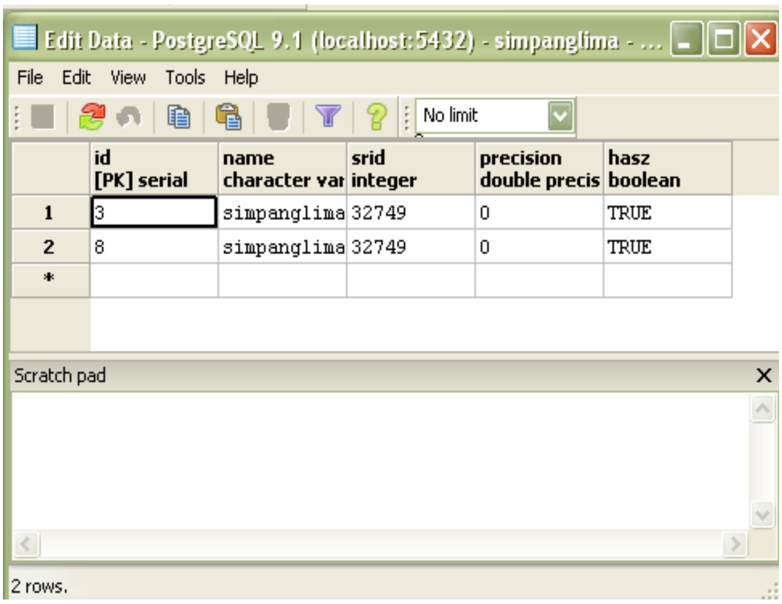
64 rows.

Figure 3. Table public.topologi

The results of the topology structure of the room objects consist of two parts that are stored in separate columns, which corresponds to the top and bottom of the room. Topology column has a topogeometry type that is the type of composition representing a topology geometry object. Topology geometries in this study are topogeometry of the top of the room that is stored in the `t1_topo` column and topogeometry of the bottom of the room that stored in the `t2_topo` column.

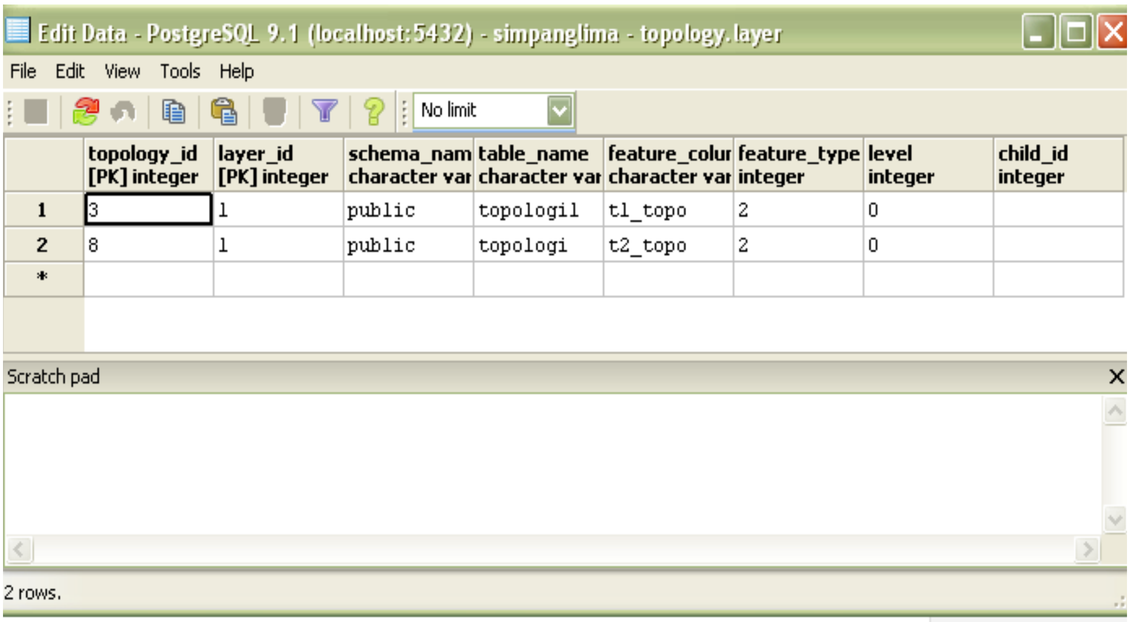
A topogeometry is a storage composition as presented in the content column of `t1_topo` and `t2_topo` in Figure 3. Topogeometry elements respectively contain data related to `topology_id`, `layer_id`, `id integer`, and `integer type`. For example, topogeometry `(3, 1, 1, 2)`, digit `'3'` means topology id of the object when registered in the topology table of the topology schema. Digit `'1'` means layer id of the topology object, where one layer presented one type of topology object. Because in this research using one object, that is a room, so that there is just one layer. The next numeral `'1'` declares a unique sequence that defines the topogeometry in the pertinent topology layer. And the digit `'2'` explains geometry type, where 1 is `[multi]point`, 2 is `[multi]line`, 3 is `[multi]poly`, and 4 is `collection`.

Using PostgreSQL software, all functions that can be implemented against the topology-based structure database exist in the topology schema. This schema is not only providing access to available functions but also registering the topology that is created. In this topology there are layer and topology tables. Topology table (Figure 4) defines a unique id, name, SRID (spatial reference id), topology tolerance, and whether the Z value of each pairing coordinates are specified or not. Table of layer (Figure 5) representing objects do topology. In this table the object was defined its topology id, layer id, where the schema that contains topology results table is, consisting column names and its feature type.



	id [PK] serial	name character var	srid integer	precision double precis	hasz boolean
1	3	simpanglima	32749	0	TRUE
2	8	simpanglima	32749	0	TRUE
*					

Figure 4. Table of topology



	topology_id [PK] integer	layer_id [PK] integer	schema_nam character var	table_name character var	feature_colur character var	feature_type integer	level integer	child_id integer
1	3	1	public	topologi1	t1_topo	2	0	
2	8	1	public	topologi	t2_topo	2	0	
*								

Figure 5. Table of layer

The spatial data of the topology structure stored in a separate schema. Each schema consists of four tables, namely: tables of `node`, `edge_data`, `face`, and `relation`. This study produced two schemas that store spatial data the topology structure and had been enrolled in the topology schema. The two schemas are `simpanglima_topo1` schema that stores the spatial data of the upper room and `simpanglima_topo2` that store the spatial data of the bottom room.

The visualization of the objects could be presented by using X3D format. Figure 6 below showed one object from the result of the topology development.

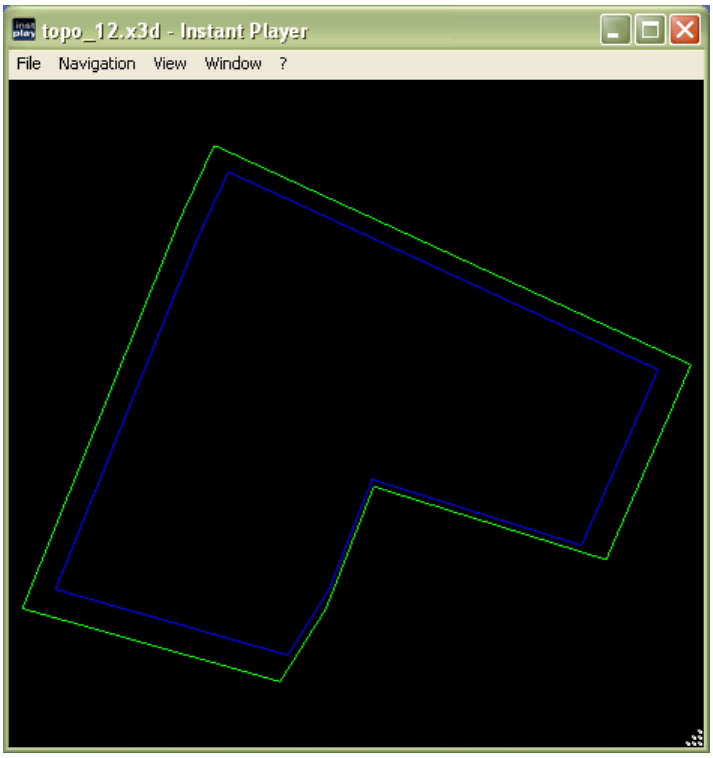


Figure 6. Visualization the Objects in X3D Format

3.2 Analyses of Real Cadastre Cases

Cases related to cadastre determined in this study based on the use of room as an apartment (flat). Problems associated with the common parts, shared objects, and land together. Here's some information needs associated with utilizing spatial data of databases of topology structure at Simpanglima Semarang Rusun Plasa.

Case 1 : Shows the room which is directly adjacent to the specified room (the horizontal direction).

Query expression Case 1:

```
select r_id as ruang
from (select st_asewkb(t1_topo) as p from topologi where r_id
       ='r_001') as a,
       (select r_id, st_asewkb(t1_topo) as q from topologi where
       not r_id = 'r_001') as b
where st_overlaps(st_geomfromewkb(a.p),st_geomfromewkb(b.q))
```

Result Case 1:

```
r_002, r_003, r_004
```

Case 2 : Shows any room that is directly adjacent at above and below the specified room (the vertical direction).

Case 3 : Indicate in which land parcel the room on the firstfloor was on it.

Query expression Case 3:

```
select geom2.bt_id as bidang_tanah
from (select st_asewkb(t2_topo) as a from topologi where
        r_id='r_024') as geom1,
       (select bt_id, st_makepolygon(st_addpoint(geom.g,
        st_startpoint(geom.g))) as b
       from (select bt_id,bt_geomline as g from bidang_tanah) as
        geom) as geom2
where
st_contains(st_geomfromewkb(geom2.b),st_geomfromewkb(geom1.a))
```

Result Case 3:

```
1
```

Case 4 : Indicate in which land parcel the room at another floor was on it.

Case 5 : Inform rooms anywhere on the first floor that the entire room is above a certain land parcels.

Query expression Case 5:

```
select geom1.r_id as bidang_tanah
from (select r_id, st_asewkb(t2_topo) as a from topologi) as
       geom1,
       (select st_makepolygon(st_addpoint(geom.g,
       st_startpoint(geom.g))) as b
       from (select bt_geomline as g from bidang_tanah where
       bt_id=2) as geom) as geom2
where
st_contains(st_geomfromewkb(geom2.b),st_geomfromewkb(geom1.a))
```

Result Case 5:

```
r_061, r_062, r_063
```

Case 6 : Inform rooms anywhere at another floor that the entire room is above a certain land parcels.

Case 7 : Mention any rooms on the first floor which is above the two land parcels at once.

Query expression Case 7:

```
select geom1.r_id as bidang_tanah
from (select r_id, st_asewkb(t2_topo) as a from topologi) as
      geom1,
      (select st_makepolygon(st_addpoint(geom.g,
      st_startpoint(geom.g))) as b
       from (select bt_geomline as g from bidang_tanah where
      bt_id=1) as geom) as geom2,
      (select st_makepolygon(st_addpoint(geom.g,
      st_startpoint(geom.g))) as c
       from (select bt_geomline as g from bidang_tanah where
      bt_id=2) as geom) as geom3
where
st_intersects(st_geomfromewkb(geom2.b),st_geomfromewkb(geom1.a))
and
st_intersects(st_geomfromewkb(geom3.c),st_geomfromewkb(geom1.a))
```

Result Case 7:

```
r_060, r_064
```

Case 8 : Mention rooms anywhere at another floor that the room above the two land parcels at once.

Case 9 : Shows the line geometry that is the boundary of the wall directly adjacent to or shared (horizontal direction).

Query expression Case 9:

```
BEGIN;
create view tab1 as
select b.r_id as id1, st_astext(st_geomfromewkb(a.p)) as geomt1
from
     (select geom2.g2 as p
      from (select t1_topo as g1 from topologi where t1_id =2) as
             geom1,
            (select geom as g2 from simpanglima_topo1.edge_data) as
             geom2
      where st_contains(geom1.g1,geom2.g2)) as a,
     (select r_id, st_asewkb(t1_topo) as q from topologi where not
      r_id = 'r_002') as b
where st_within(st_geomfromewkb(a.p),st_geomfromewkb(b.q));

create view tab2 as
select d.r_id as id2, st_astext(st_geomfromewkb(c.r)) as geomt2
from
     (select geom2.g2 as r
      from (select t2_topo as g1 from topologi where t1_id =2) as
             geom1,
            (select geom as g2 from simpanglima_topo2.edge_data) as
             geom2
      where st_contains(geom1.g1,geom2.g2)) as c,
     (select r_id, st_asewkb(t2_topo) as s from topologi where not
      r_id = 'r_002') as d
where st_within(st_geomfromewkb(c.r),st_geomfromewkb(d.s));

create view tab3 as
select f.r_id as id3, st_astext(st_geomfromewkb(e.t)) as geomt3
from (select g_geom as t from garis,bagian_dari where
       garis.g_id=bagian_dari.g_id and t1_id=2) as e,
      (select r_id, g_geom as u from topologi,garis,bagian_dari
       where garis.g_id=bagian_dari.g_id and
       bagian_dari.t1_id=topologi.t1_id and not
       bagian_dari.t1_id=2) as f
where st_3dintersects(st_geomfromewkb(e.t),st_geomfromewkb(f.u));
COMMIT;
```

Results Case 9:

The `LINESTRINGZ` geometry

Case 10 : Indicates the line geometry which is the boundary of the roof or floor directly adjacent to or shared (the vertical direction).

Case 11 : Mention the rooms that are in the same hallway or corridor.

Case 12 : Mention the hallway or corridor at the specified room.

Cadastre Cases	Ability of Database
Case 1	V
Case 2	X
Case 3	V
Case 4	X
Case 5	V
Case 6	X
Case 7	v
Case 8	x
Case 9	v
Case 10	x
Case 11	x
Case 12	x

Figure 7. Ability of Database

In Figure 7, the Cadastral Cases column covers a list of cases has been pesented previously. The Ability Database column indicates whether the cases can be solved by the corresponding query. The (v) check mark means that the cases can be solved by using query database of topology structure.

Case 1, Case 3, Case 5, Case 7, and Case 9 is a case for the first floor, while Case 2, Case 4, Case 6, Case 8 and Case 10 were cases involving spatial data other than the first floor. Because the study did not use spatial data other than the first floor the cases that require spatial information other than the first floor do not query. Incomplete spatial data is also a cause can not be completed Case 11 and Case 12. Both cases are cases that require spatial information about the object corridor or hallway, while the study did not use spatial data objects hallway or corridor.

4. CONCLUSIONS

The development produces a database of topology structure which are not capable of describing the object as a whole space either solid or skeleton-shaped object. Only part of the space in the form of plane can do topology. Part is the upper chamber and the lower chamber.

Implementation of 3D spatial database result of the research to the real cases related cadastral flats is able to provide information space next to each other, indicate a space of land, inform the entire space above the ground plane, exhibit space located on two parcels of land, and exhibit space adjacent geometry. Questions cannot be answered databases arises due to exclusion of spatial data objects instead of space and spatial data other than the first floor in a database.

In solving the cases that related cadastre, the database of topology structure of this research limited in giving the information. This causes the lacking of the spatial data that used in this research. In order to fulfill the need of the information and solve the cases, it is necessary to add spatial data and the attributes of the other floor and the corridor.

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BIOGRAPHICAL NOTES

Trias Aditya is Associate Professor in the Department of Geodetic Engineering, Gadjah Mada Univeristy (UGM), Indonesia. He completed his MSc and PhD degrees in Geoinformatics from ITC, the Netherlands. His research interests include interoperable LIS/GIS and Geovisualization and his latest research projects are 3D Cadastre, Spatial Data Infrastructure, and Collaborative Mapping .

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