Visually Analyzing Evolution of Geographic Objects at Different Levels of Details Over Time

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Abstract. Evolutionary history of geographic objects ($EHGO_S$) in three-dimensional (3D) space at different levels of details ($DLOD_S$) over time is due to natural law or imposed by humans and always goes on every day. To represent visualization this evolutionary history, this paper proposes visual analysis of $EHGO_S$ at $DLOD_S$ over time, results of visual analysis are a model of representation of visualization of GO_S at $DLOD_S$ over time, this model is called $TLOD_S$. Time is the class that records the time of formation and loss of GO_S. Time in this paper is divided into three main categories and integrate into the TLODs model, namely legal time (LT_S), event time (ET_S), and database time (DT_S). When manipulating queries can be either point of time or period of time in three types of time. This paper presents the experimental setup of the $TLOD_S$ model in Oracle 11G and incorporating in C# to represent typical forms. Experimental results show that it can be applied to the management of urban technical infrastructure in practice.

Keywords: Geographic objects · $DLOD_S$ · $TLOD_S$ · Visual analysis
Visual representation

1 Introduction

Geographic objects (GO_S) are objects in 3D space. Afterwards temporal geography is developed, GO_S are objects of space and time [1]. The design of 3-4D GIS data model will directly impact to visual representations of data, storing of data, retrieving of data, and analyzing visualization of data for geographical objects in 3D space. And especially more important when designing a 3-4D GIS data model, this 3-4D GIS data model must be able to answer users' questions raised by various criteria that belong to field of regulation.

Throughout the long history of GIS development, lots of the 3-4D GIS data models were proposed, but most of these models only represent 2.5-3D objects. This paper summarizes the research as follows: Cadastral 3D model was proposed by author Ding and colleagues in 2017 [2]; the TUDM model was proposed by the author team Anh

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and colleagues in 2012 [3]; the VRO-DLOD3D model was proposed by Dang and colleagues in 2017 [1]; the CityGML model was proposed by Groger and colleagues in 2008 [4]; the author team Kolbe and colleagues have expanded the CityGML model in 2009 [5]; the author team Biljecki and colleagues improved the CityGML model by 2016 [6]; the author team Dang P.V. and colleagues proposed the ELUDM model for 2.5D objects in 2011 [7]; the author team Anh and colleagues proposed ELUDM model for 2.5-3D objects in 2011 [8]; the author team Löwner and colleagues proposed a new LoD and multi-representational concept for the CityGML model in 2016 [9]; The CityGML-TRKBIS.BI model was proposed by Aydar and colleagues to respond the need to establish 2-2.5-3D national Turkey by 2016 [10], etc. These researches will be presented in detail in Sect. 2. By summarizing the above-mentioned researches, we have found that no author group refers to the visualization of the evolutionary history of GO_S in 3D space at the $DLOD_S$ over time.

$EHGO_S$ (GO_S include: housing, population, geographical space, furniture, etc.) at the $DLOD_S$ over time is very diversified and complex. Diversity is represented in the design, style, size, and color of the GO_S. Complexity is represented in spatial dimension, linkage between geographic objects and time dimension. In particular, the evolutionary history of GO_S in urban technical infrastructures is now of great interest by urban managers, as the management of GO_S which is a residential building in residential areas is a very hot topic today. People must take advantage of the high space to make up for the limited land fund.

The objective of this paper is to visualize the $EHGO_S$ in 3D space at $DLOD_S$ over time. Result in representing $EHGO_S$ is an extremely important stage in the development of urban planning today. Thanks to the management of the evolutionary history of these geographic objects, we can see the development and disappearance process of GO_S. At different levels of details at the same time, GO_S will be born and gone, and such management is essential for levels of urban infrastructure in the future. When demonstrating blocks 2-2.5-3-3.75-4D, we are interested in how to display these objects at $DLOD_S$ over time. These details depend on the different needs of the application, location, or different requirements for the same application. In computer graphics $DLOD_S$ are often used a lot. $DLOD_S$ are the hierarchy of resolution when compared to the real world. $DLOD_S$ is a quick representation of a 3D space model, indicates the degree of voltage abstraction for objects. $DLOD_S$ of a low level object are called low resolution levels, otherwise called high resolution. When performing an object into a computer, we need to represent it in such a way that it is in the real world.

The remainder of paper is organized as follows. Section 2 presents overview of GIS data models and comments and suggestions. Section 3 performs a visual analysis of the evolutionary history of GO_S in 3D space at $DLOD_S$ over time and with some illustrations. Section 4 illustrates experiments. Conclusion is in Sect. 5.

2 The GIS Data Models

2.1 Overview of the GIS Data Models

Throughout the long history of the development of 0-dimensional, one-dimensional, two-dimensional, 2.5-dimensional, three-dimensional, 3.75-dimensional, and four-dimensional geographic information systems (0-1-2-2.5-3-3.75-4D GIS), including the great contributions of researchers on GIS, they have proposed many spatial, temporal, and semantic data models. These models are chosen as the premise for the development of residential GIS management systems over time, management of urban technical infrastructure, mining management, disaster management, land management, or epidemiological management, etc. These models are illustrated detail below.

2.1.1 3D Cadastral Model

In 2017, author Ding and associates [2] proposed the extrusion approach based on non-overlapping footprints (EABNOF) to build the geometry model and topology in the 3D Cadastral Model. EABNOF handles the case of complex 3D blocks. To reach EABNOF, the overlap between the overlapping traces of the input data files will be removed, including the division of the extrusion and processing traces of cadastral objects to fit together. The trace against new cross was born will be extruded to produce the original copies. To build the geometry model and topology for cadastral objects, there are 3 proposed evaluation criteria to identify and remove the excess from the original and then the original version of the composition space the same 3D or the features of the link structure will be incorporated. Special sections of EABNOF approach that groups of authors have applied to 2D data sets. The author team has tested two types of structures on the Pozi verifies EABNOF approach: a complicated building and the furniture. EABNOF based on the traces of the 2D cadastral data sets and especially consistent with areas of the sets of 2D cadastral data to setting 3D cadastral system with lower costs.

2.1.2 TUDM Model

TUDM was a model of 4D spatial - temporal data proposed by Anh and coworkers in 2012 [3]. These authors have focused on developing a time dimension to integrate into the known 3D GIS space model. The time dimension in TUDM can be a time or a time period. The birth and extinction time of an object in TUDM can either be in the real world or be recorded in the database. TUDM can represent and store not only the evolutionary history of 0D, 1D, 2D objects but also the life cycle of 3D objects.

2.1.3 VRO-DLOD3D Model

The VRO-DLOD3D model was proposed by Dang and colleagues in 2017 [1]. The author group has researched and developed a visual representation of geographic features (people, buildings and geospatial space) along with relationships (blood relations, social relations, previous conviction relations, previous offence relations and vital relations) in three dimensions at different levels of detail, serving the protection of security and social order and safety in the area. The author group also presents data in forms through a number of typical queries at different levels of detail.

2.1.4 CityGML Model

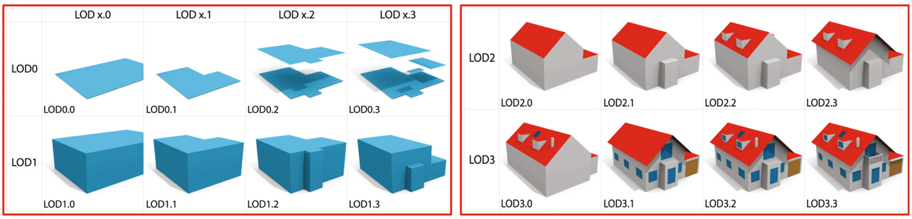
CityGML model by Groger and colleagues proposed in 2008 [4]. The idea behind this model is to build a 3D city model as a model platform and open XML. The main purpose of CityGML is to develop common definitions related to the entities, attributes, and relationships in the model 3D cities to the different applications can share a common data source. CityGML is represented by objects of geometry GML3. This model is based on ISO 19107. Standard CityGML has an attribute not only space but also a semantic attribute. CityGML model supports 5 levels of detail (LOD): LOD0 is the most rugged, mostly 2.5D digital terrain model; LOD1 a block model, the buildings are represented as blocks with flat roofs; in LOD2 more complex buildings can be modeled, complex roof, settings such as stairs and balconies are available; LOD3 allow architectural models, may have detailed the walls, roof, doors gates, etc.; LOD4 completed LOD3 and include internal structure, such as guest rooms, doors, stairs, furniture, etc. It can be shown the same object in different LOD.

2.1.5 Improved the CityGML Model (a)

Author Kolbe and colleagues in 2009 [5] was used CityGML model and combined building new models for application in a number of German cities. These cities include, buildings, furniture, vegetation, land use, water areas, transportation (streets, rails, etc.) are defined in modules subject matter may be open wide in the future.

2.1.6 Improved the CityGML Model (b)

The author group Biljecki and colleagues [6] have improved CityGML model by refining LOD. This improvement increases the level of detail of the detailed CityGML from 5 to 16 the level of detail. This improvement is made using a geometric display. Each level of CityGML is smoothed over 4 times, as illustrated in Fig. 1 (see left and right).



(left) (right)

Fig. 1. Visual illustration of 16 LODs smoother for a residential building [6]

2.1.7 ELUDM Model for 2.5D Objects

ELUDM (Enhanced Levels of detail Urban Data Model) was a model proposed by Dang P.V. and coworkers in 2011 [7]. These authors have proposed the addition of LOD (Levels of Detail) and complex links between Surface, Line, Point and LOD to the ELUDM to serve visual representation of 2.5D objects at multiple different levels.

User defines the number of levels. The diversity of the visualizing will respond the requirements of different applications. This approach can extend for LOD of objects 3D that not depend on semantic.

2.1.8 ELUDM Model for 2.5-3D Objects

The ELUDM model was proposed by the author team Anh and colleagues in 2011 [8]. The author team proposed adding more complex linkages to the existing data model to improve visibility for Surface Objects (2.5D) and Body (3D). The author team also proposed to remove semantic objects to become the purest spatial data model. This new model is capable of rendering 2.5D and 3D objects at detailed levels. Users can define multiple levels of detail.

2.1.9 The Multi-representational Concept for CityGML

The author team Löwner and colleagues proposed a new LoD concept and multi-representational concept [9] for the CityGML model that allowed the user to define LoDs arbitrarily. The author team also proposed using the concept of multi-representation as a meta-model to allow users to define more than one LoD concept for the CityGML3.0 model.

2.1.10 The CityGML-TRKBIS.BI Model Extending from CityGML Model

The author team Aydar and colleagues proposed the creation of a geographic data model for Turkey 3D [10], which is compatible with OGG International's CityGML code. The author team has also prepared an ADE called CityGML-TRKBIS.BI created by extending the existing specialized modules of the CityGML model according to the needs of the TRKBIS geographic data model. All thematic data sets in the TRKBIS geographic data model were modified to generate large-scale 3D geographic data models for Turkey 3D. The 3D geographic data model developed for the construction of thematic layers will be used as a general transformation format to meet the need to establish 2D, 2.5D, and 3D objects at the national level.

2.1.11 UDM Model

UDM (Urban Data Model) was a model of spatial data proposed by Coors in 2003 [11] based on four basic objects POINT, LINE, SURFACE, BODY. UDM uses two elemental objects NODE, FACE. ARC isn't proposed in this model. Each FACE is defined by 3 NODEs, so the model reduces some NODE-ARC, ARC-FACE relationships. Some topology relationships such as NODE are on FACE, NODE in BODY is not described. The obvious advantage of the UDM is the efficient data storage, the object-oriented analysis which is used urban management applications and representation of faces and blocks based on triangulation.

2.1.12 3D Array Model

Array 3D model was proposed by Rahman in 2005 [12, 13]. Models with simple data structures used to represent most of the 3D object. The 3D elements in the Array have the value 0, 1. In the description that the base value of 0, 1 describes the value that each element in the 3D Array occupied by 3D objects. If a 3D object is being scanned in a 3D array which element of the array is initialized with the initial value 0. After scanning to 3D objects, elements worth 1 present information for 3D objects. If scanning 3D objects with high resolution, the size of the array in each direction will increase as volumetric 3D data should describe also increased and require large storage space.

2.1.13 Octree Model

Octree model is an extension of the quadtree into the octal tree. Octree representation is a 3D model based on volume [13, 14]. Octal tree gives us the picture, this is a method represented by the data structure tree. Generally, an octal tree is defined based on a cube that contains the smallest 3D objects needs performing. Original cube will be divided into 8 cube offspring. An octal tree is based on the decomposition of recursive algorithm follow. Each Node in the tree is or leaf, or 8 seedlings. Each seedling will be checked before being divided into 8 different seedlings.

2.1.14 CSG Model

The model CSG was proposed by Rahman in 2008 [12, 13]. CSG performed a 3D object by combining the 3D element has been defined before. The basic 3D blocks such as: cube, cylinder, and sphere. The relationship between the figures includes: transformation and the mathematical treatise storage class. These transformations include translation, rotation, allowed to measure change. The comment class storages include union, intersect and except. CSG is often used in CAD. CSG is very convenient in the calculation of the volume of the object, so the CSG does not conform to the performance for the objects have unusual geometric shapes.

2.1.15 The Method Boundary Representations (B-REP)

The method B-REP (Boundary Representations) uses to represent the object 0-1-2-2.5-3D based on the elements already defined in advance, including: point, line, surface, and blocks. In which, the Line could be the line segment, the arch, the circle; Surface may be flat, the surface polygons created by the circle, cone, the surface of the cylinder; Solid is the expansion of the surfaces to gig the 3D blocks, the blocks can: box, cone, cylinder, the combination of this block or a block of any [12, 13]. Therefore, appropriate B-REP method to gig for the space object has a shape often, artificial, and scalar. B-REP focuses on building objects and relationships between them [15].

2.1.16 Combined Model Between B-REP and CSG

The B-REP+CSG model by Chokri and colleagues were suggested in 2009 [16]. The model is based on the idea of performing 3D objects by combining the 2 methods of B-REP and CSG. In B-REP models using 4 basic object point, line, surface, and solid. A line is defined by the first and last points 2. A surface is defined from a closed string (Closed-string) with or without direction. A surface may be full or empty. Empty_-surface to describe the gap. Many surfaces in the same plane make up Composit_-surface. A solid is represented by a set of surrounding surfaces. Solid may be full or empty. FULL_Solid is created by a set of scalar surfaces, so the interior of Solid is not modeled. In CSG element objects include cylinders, spheres, and prisms. A CSG_Composit is the union, intersect, except of 2 Solids. The inside of Solids is not modeled. The cubes, triangular prisms, polygonal prisms are the derivative objects of the prisms. The advantage of this approach is based on the advantages of the B-REP method, which demonstrates very well the external boundaries that make up the object and the advantage of the CSG approach is the minimization of storage data.

2.2 Classification of the Data Models

Selecting 3D data models to represent 3D GIS objects for a particular application will determine the storage methods, access methods, management methods, and processing methods when display and data bindingness will also be different. A model can combine all fields is not practical. The data models were proposed by the authors will be analyzed and synthesized in this paper. It was divided into four main categories, and had the following categories of data models (see Table 1).

Table 1. Classification of the models

Model types	Name of the models
B-REP (B)	3D Cadastral model, TUDM model, VRO-DLOD3D model, UDM model, CityGML model, Improved the CityGML model (a and b), ELUDM model for 2.5D, ELUDM model for 2.5-3D, Multi-representational concept (MRC) for CityGML model, CityGML-TRKBIS.BI model extending from CityGML model
VOXEL (V)	3D Array Model, Octree Model
CSG (C)	CSG Model
COMBINING B-V-C	B-REP and CSG

Type 1: *Representation of 3D objects by B-REP. B-REP method to represent a 3D object-based element has been defined, including: Point, Line, Surface, and Solid. B-REP suitable for representing 3D objects shaped conventional and scalar. B-REP focuses on building objects and the relationships between them [15].*

Type 2: *Representation of 3D objects by voxel elements such as pixels in 2D GIS. Voxel method represents a 3D object based on ideas split an object into sub-elements, each element is called a voxel child [17]. One element to be considered as a geographical space and is assigned by an integer [18].*

Type 3: *Representation of 3D objects by combining the basic 3D blocks [12, 13].*

Type 4: *Representation of 3D objects by combining three types above*

2.3 Commentation and Suggestion TLODs Data Model

Through the synthesis and classification of data models suggested by the authors in the past, we have the following observations. Through the below comments, we have some suggestions as follows: (1) Combining space components to become residential buildings or villas located on limited land funds, (2) Applying B-REP method for new TLODs model, and (3) Visually analyzing evolution of geographic objects to build $TLOD_S$ data model. The $TLOD_S$ model is capable of answering users' questions about the topic: "Visual representation the evolutionary history of geographic objects at different levels of details in the 3D geographic space over time". Within the scope of this paper, we only analyze, construct and manage geographic objects that are residential buildings or villas. In the next section, we perform a visual analysis of these GOs to integrate these GOs into entities such as LOD_S, $PRISM_S$, $SURFACE_S$, $LINE_S$, $POINT_S$, $TIME_S$, MDY_S, and $TIMETYPE_S$.

Comment 1: Most models use the B-REP method.
Comment 2: The models have not mentioned to represent GO_S at $DLOD_S$ over time.
Comment 3: The combination of space components to become a residential building also has not yet been mentioned.
Comment 4: Most models represent only one-level for the 3D-block except the CityGML, MRC, CityGML-TRKBIS.BI, and ELUDM models which represent 2.5-3D objects at the detail levels, but these models also do not mention the evolutionary history of GO_S at $DLOD_S$ over time. In addition, the CityGML, Improved CityGML, MRC, and CityGML-TRKBIS.BI models are 3D models which have rich semantics. CityGML has four or five detail levels, while MRC and CityGML-TRKBIS.BI have an arbitrary level of details; ELUDM model is a non-semantic model and has an arbitrary level of details.

3 Development of TLODS Model

3.1 Visual Analysis the $EHGO_S$ at $DLOD_S$

To construct 3D objects that are residential buildings or villas, this paper integrates spatial components from various $PRISM_S$ ($\mathbf{BP_S}$ and $\mathbf{BC_S}$), $SURFACE_S$ ($\mathbf{S_S}$), $LINE_S$ ($\mathbf{L_S}$), and $POINT_S$ ($\mathbf{P_S}$) objects to form residential buildings or villas and apply the B-REP method for demonstrating these spatial components. We illustrate some residential areas to visually analyze the evolutionary history of residential buildings or villas at different levels of details over time located on limited land funds. Figure 2 illustrates the results of a visual analysis of the evolution history of the villa named "Bee Villa" at various different levels of details located on a limited land funds. Through the results of visual analysis of Fig. 3, we performed the results of Fig. 3 in database of $TLOD_S$ model (see Table 2) and will be experimentally installed in the next Sect. 4.

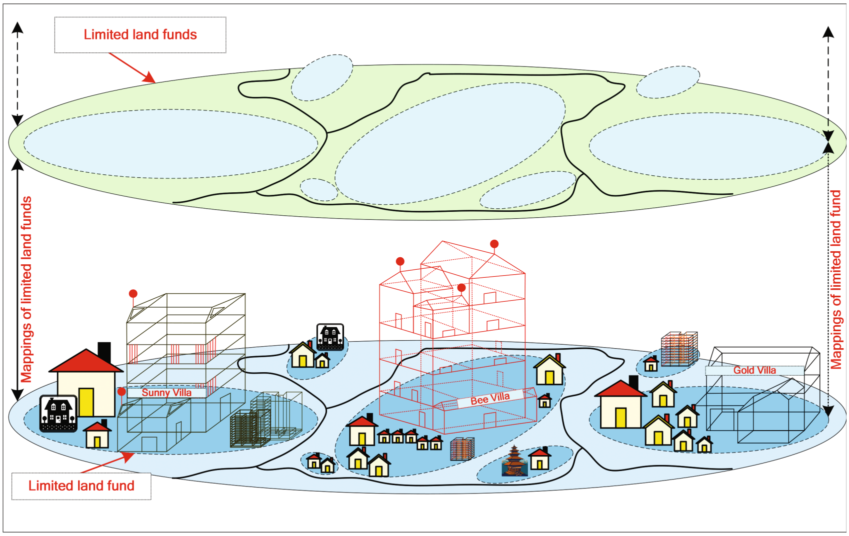


Fig. 2. An illustration of residential areas with residential houses or villas located on limited land funds

3.2 To Develop $TLOD_S$ Data Model

The time class is used to map during the creation progress of one or more GO_S at $DLOD_S$, such as a villa or residential house. This mapping will keep track of the $EHGO_S$ at $DLOD_S$. There are three types of time to be applied [19] (Fig. 4), which are: (1) Legal time (LT_S) is the effective time in the legal document *(with month-day-year-hour:minute:second start and month-day-year-hour:minute:second end on the legal document)*; (2) Event time (ET_S) is time of start of formation and end of loss in the real world *(with month-day-year-hour:minute:second start and month-day-year-hour:minute:second end in the real world)*; (3) Database time (DT_S) is the start and end time of recording in the database *(with month-day-year-hour:minute:second start and month-day-year-hour:minute:second end in the database)*. Forms of time include: point of time or period of time (Fig. 5), we have:

- The link between $TIME_S$ and $TIMETYPE_S$ indicates the time format of three types of time (Fig. 4).
- The link between $TIME_S$ and MDY_S indicates the time format of either instant time or interval time (Fig. 5).

At one level $DLOD_S$ can have multiple $PRISM_S$ A, $SURFACE_S$ A, $LINE_S$ A, and $POINT_S$ A created for a villa or residential building over time. Thus, we created a four-branch connection that indicates a $PRISM_S$ A, $SURFACE_S$ A, $LINE_S$ A, and $POINT_S$ A will either be created or lost and will be visualized at different levels of details, some $DLOD_S$ for a villa or a residential building over time. Corresponding to visual representation data models for villas or residential buildings at a different level of details over time, we have:

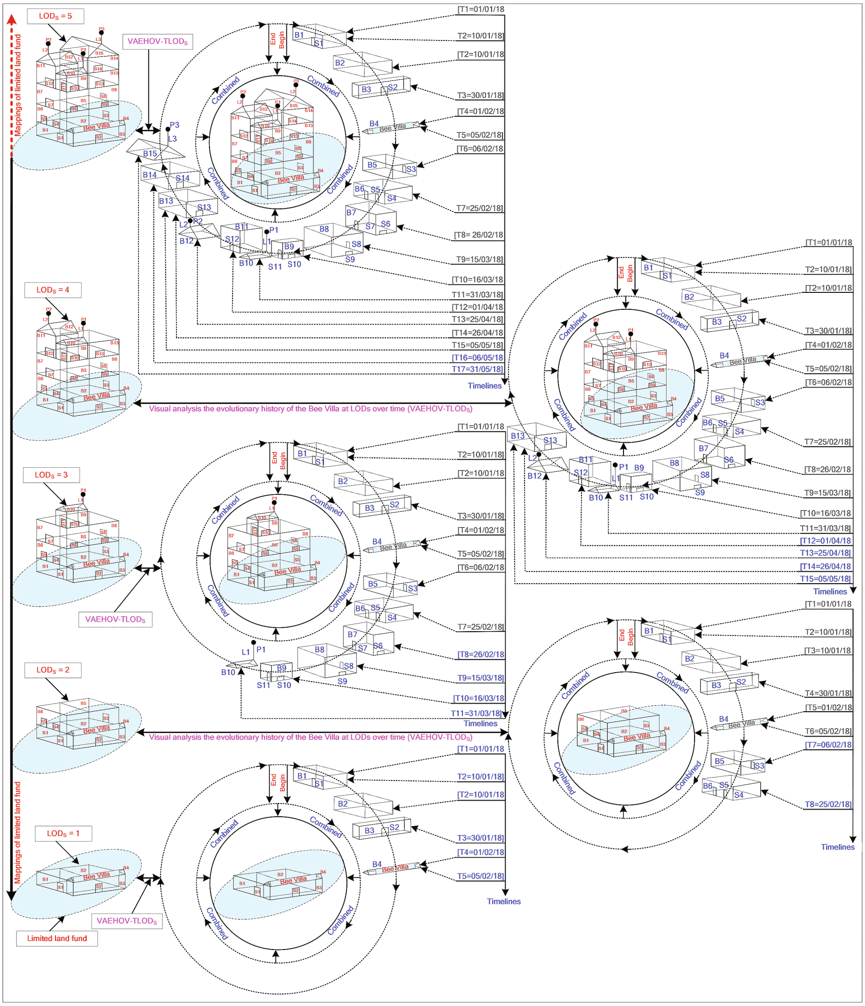


Fig. 3. Visual analysis the evolutionary history of Bee Villa (shown in Fig. 2) at DLOD_S over time is located on a limited land funds.

- The four-branched linkage between four DLOD_S objects, PRISM_S(Children), PRISMsP (Parent) and TIME_S indicates that a PRISM_S will be generated or lost at a certain interval time *(For example, a $PRISM_S$ A is born from January 1, 2018 to March 30, 2018, and from May 05, 2018 to May 28, 2018 $PRISM_S$ A will be lost.)* and will be visualized at the DLOD_S level and for any villa (see Fig. 6).
- The four-branched linkage between the four DLOD_S, SURFACE_S, PRISMsP (Parent), and TIME_S indicates that a SURFACE_S will be born or lost at a certain period of time *(For example, a $SURFACE_S$ A is born from January 10, 2018 to*

Table 2. The Bee Villa was shown evolutionary history at five different levels of details and represented in the database of the Oracle.

Represented Bee villa in the database of the Oracle											**A display of different levels of details of the Bee villa**
Timetype$_S$		**BPs**				**DLOD$_S$**					
Event time		Bee Villa									
Time$_S$											
Start	**End**	**BCs**	**Ss**	**Ls**	**Ps**	**1**	**2**	**3**	**4**	**5**	
…	…	…	…	…	…	.	.	.	.	.	…
06/05/18	31/05/18	B14 B15	S14	L3	P3						
26/04/18	05/05/18	B13	S13								
01/04/18	25/04/18	B11 B12	S12	L2	P2						
16/03/18	31/03/18	B9 B10	S10 S11	L1	P1						
26/02/18	15/03/18	B7 B8	S6 S7 S8 S9						Level 4	Level 5	
06/02/18	25/02/18	B5 B6	S3 S4 S5					Level 3			
01/02/18	05/02/18	B4					Level 2				
10/01/18	30/01/18	B2 B3	S2			Level 1					
01/01/18	10/01/18	B1	S1								

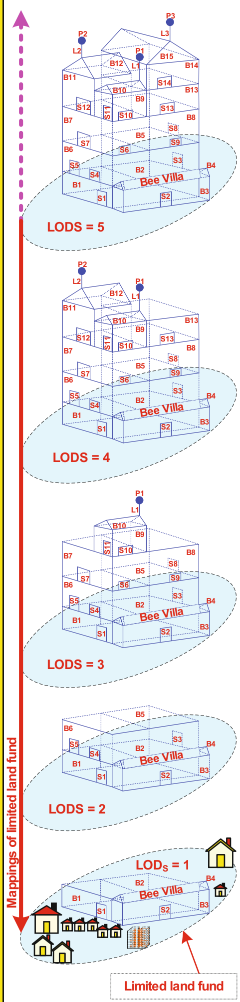


Fig. 4. Data model expresses linkage between TIMES$_S$ and TIMETYPE$_S$

Fig. 5. Data model expresses linkage between TIMES$_S$ and MDY$_S$

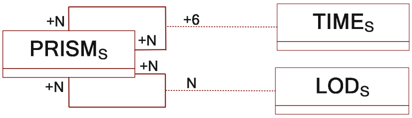


Fig. 6. Data model expresses linkage between PRISMsP (Parent), PRISM$_S$ (Children), TIMES$_S$, and LOD$_S$.

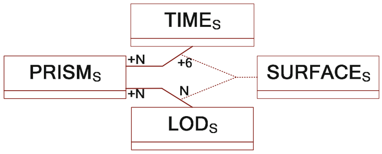


Fig. 7. Data model expresses linkage between PRISMsP (Parent), SURFACE$_S$, TIMES$_S$, và LOD$_S$.

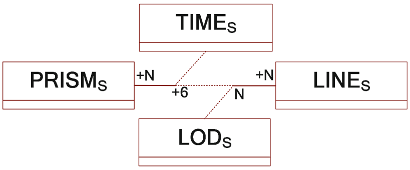


Fig. 8. Data model expresses linkage between PRISMsP (Parent), LINE$_S$, TIMES$_S$, và LOD$_S$.

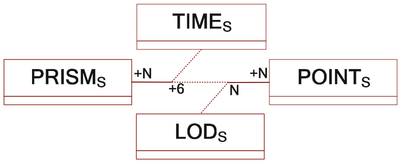


Fig. 9. Data model expresses linkage between PRISMsP (Parent), POINT$_S$, TIMES$_S$, và LOD$_S$.

March 15, 2018, and from May 10, 2018 to May 30, 2018 SURFACE$_S$ A will be lost.) and will be visualized at any DLOD$_S$ level and for which villa (see Fig. 7).

- The four-branched linkage between the four DLOD$_S$, LINE$_S$, PRISMsP (Parent), and TIMES$_S$ objects indicates that a LINE$_S$ will be generated or lost at a particular interval time *(For example, a LINE$_S$ A is born from Jan 1, 2018 to March 30, 2018, and from May 05, 2018 to May 25, 2018, LINE$_S$ A takes over.)* and will be visualized at the DLOD$_S$ level of detail and for any villa (see Fig. 8).
- The four-branched linkage between the four DLOD$_S$, POINT$_S$, PRISMsP (Parent), and TIMES$_S$ indicates that a POINT$_S$ will be generated or lost at a certain time interval *(For example, a POINT$_S$ A is generated from January 1, 2018 to March 30, 2018, and from May 12, 2018 to May 20, 2018, POINT$_S$ A will be lost.)* and will be visualized at any DLOD$_S$ level and for any villa (see Fig. 9).

Through the visual analysis of the geographic objects and integration of entities PRISM$_S$, SURFACE$_S$, LINE$_S$, POINT$_S$, LOD$_S$, TIMES$_S$, MDY$_S$ and TIMETYPE$_S$, we have come up with a new proposal model called TLOD$_S$ (see Fig. 10). TLOD$_S$ model is capable of answering users' questions/queries related to the topic "Visual representation of the evolutionary history of GO$_S$ at different levels of details in space of 3D

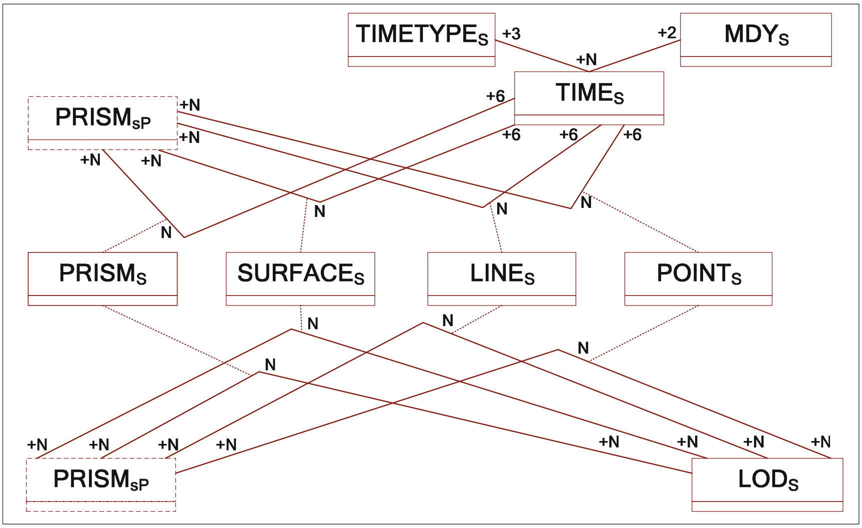


Fig. 10. TLOD$_S$ data model

geographic science over time". TLOD$_S$ model will be experimentally verified in the next section of this paper.

Decomposition of the TLODs model (see Fig. 10) gives us the following relations:

PRISMsP(#IDBP, NAME, DESCS)
PRISMs(#IDB, HEIGHT, TYPESHAPE, DESCRIPTION, ARRAYNODE)
SURFACEs(#IDS, TYPESHAPE, DESCRIPTION, ARRAYNODE)
LINEs(#IDL, TYPESHAPE, DESCRIPTION, ARRAYNODE)
POINTs(#IDP, TYPESHAPE, DESCRIPTION, ARRAYNODE)
LODs(#IDLOD, NAME, DESCS)
PRISMLODs(#IDBP, #IDB, #IDLOD, DESCS)
SURFACELODs(#IDBP, #IDS, #IDLOD, DESCS)
LINELODs(#IDBP, #IDL, #IDLOD, DESCS)
POINTLODs(#IDBP, #IDP, #IDLOD, DESCS)
TIMETYPEs(#IDTT, NAME, DESCS)
MDYs(#IDMDY, MDY, HMS)
TIMEs(#IDT, IDMDY$_{begin(b)}$, IDMDY$_{end(e)}$, IDTT, DESCS)
PRISMTIMEs(#IDBP, #IDBC, IDT$_{bLTs}$, IDT$_{eLTs}$, IDT$_{bETs}$, IDT$_{eETs}$, IDT$_{bDTs}$, IDT$_{eDTs}$)
SURFACETIMEs(#IDBP, #IDS, IDT$_{bLTs}$, IDT$_{eLTs}$, IDT$_{bETs}$, IDT$_{eETs}$, IDT$_{bDTs}$,IDT$_{eDTs}$)
LINETIMEs(#IDBP, #IDL, IDT$_{bLTs}$, IDT$_{eLTs}$, IDT$_{bETs}$, IDT$_{eETs}$, IDT$_{bDTs}$, IDT$_{eDTs}$)
POINTTIMEs(#IDBP, #IDP, IDT$_{bLTs}$, IDT$_{eLTs}$, IDT$_{bETs}$, IDT$_{eETs}$, IDT$_{bDTs}$, IDT$_{eDTs}$)
Notation: # is primary key.

4 Experiments

In this section, we perform a $TLOD_S$ model implementation in Oracle 11G and associated with the C# programming language to present the form through a number of typical queries [20–22]. We will extract a villa named "Bee Villa" in a residential area (see Fig. 11) to perform a visual demonstration of the villa's evolution at different levels of details. These experimental results demonstrate that the $TLOD_S$ model is capable of answering users' questions on the subject "Visual representation of the evolutionary history of GO_S at different levels of details in the space of three-dimensional geographic science over time". Queries will require users to provide the required input parameters, the obtained results are 3D space objects at different levels of details over time. The following are some typical queries and are accompanied by experimental results.

Query 1: Find and display the "Bee Villa" with construction time from [T1 = 01/01/2018, T2 = 31/03/2018], knew T1, T2 as period of time and type of event time (ET_S). The information of details of the show include: The villa image and details of each space component of the "Bee Villa" from T1 to T2 (see Fig. 12).

Input: The "Bee Villa" that has time from T1 to T2 is a type of ET_S.

Output: The image of the villa and time details of each space component of the "Bee Villa" villa from T1 to T2

Query 2: Find and display the "Bee Villa" with construction time from [T1 = 01/01/2018, T2 = 31/05/2018], knew T1, T2 is the time period and is type of ET_S and only display at detail level $LOD_S = 5$. Display information includes: villa image and construction time details of each spatial component of "Bee Villa" at $LOD_S = 5$ and T1 to T2 (Fig. 13).

Input: The "Bee Villa", time from T1 to T2, type of ET_S, and at $LOD_S = 5$

Output: The villa image and timing details of each space component of the "Bee Villa" at $LOD_S = 5$ and T1 to T2

Query 3: Find and display the "Bee Villa" at detail level $LOD_S = 4$ over type of ET_S. The display information includes: The villa is built at $LOD_S = 4$ and enclosed with details of the evolution of spatial components at this level.

Input: The "Bee Villa" and at level $LOD_S = 4$ over type of ET_S (Fig. 14).

Output: The villa image is built at $LOD_S = 4$ detail level and included with details of the evolutionary history of spatial components at this level over type of ET_S

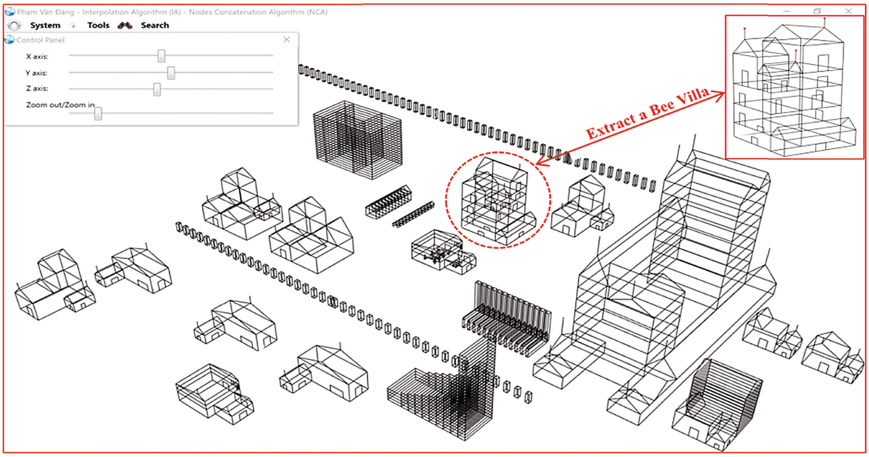


Fig. 11. A representation of urban areas including residential buildings and villas

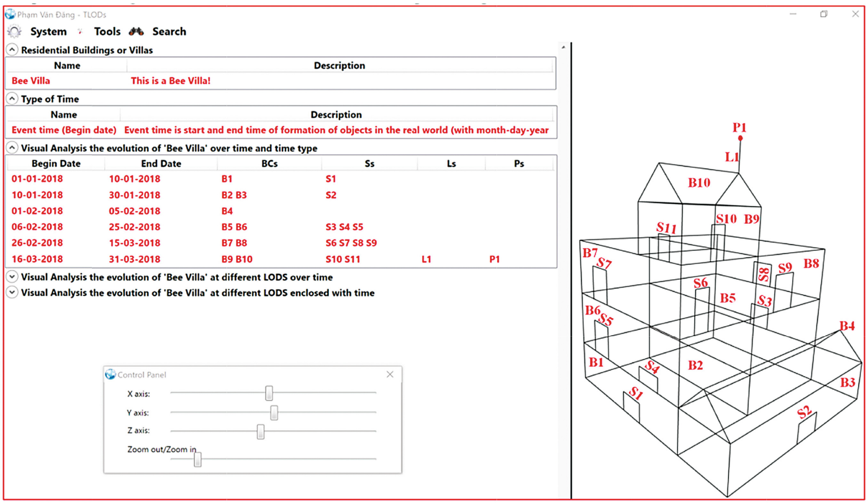


Fig. 12. The picture of “Bee Villa” and details of the time of construction of each space component of this villa from T1 to T2

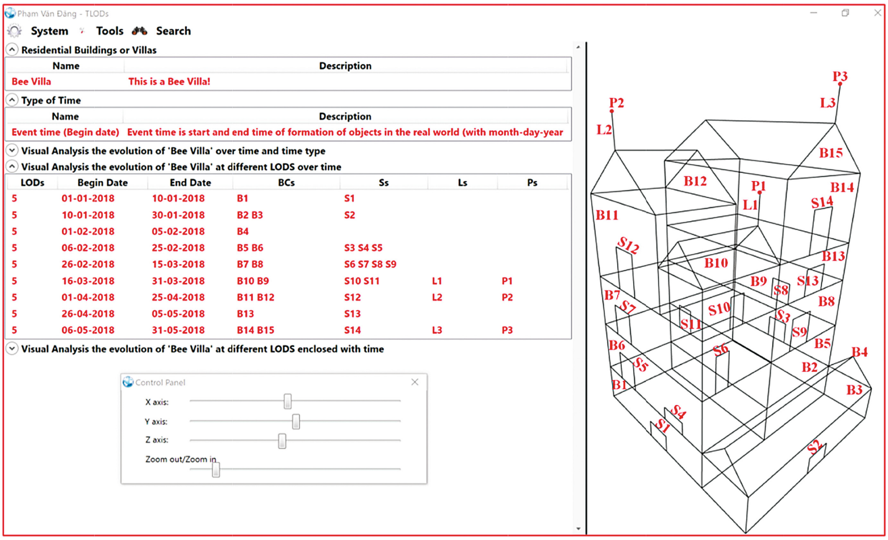


Fig. 13. The image of "Bee Villa" and detailed construction time for each spatial component of this villa at $LOD_S = 5$ from T1 to T2

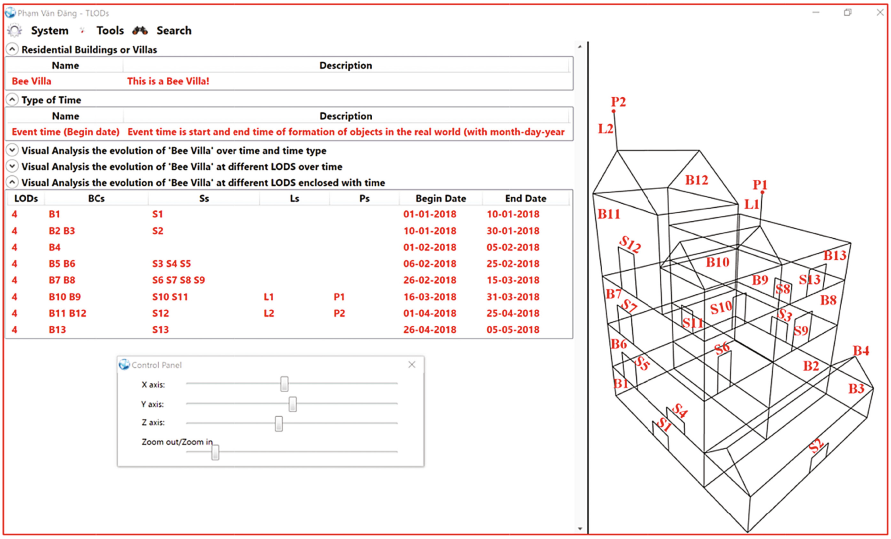


Fig. 14. The picture of the "Bee Villa" and enclosed with details of the evolutionary history of the spatial components at this level over type of ET_S

5 Conclusion

This paper was synthesized, analyzed, and categorized the GIS data models proposed by the authors over the years. Through this classification, we find that these GIS models mainly adopt the B-REP method and these GIS models do not refer to the visual representation of the evolutionary history of the geography objects at different levels of details over time. Thus, this paper has a visual analysis of the $DLOD_S$ associated with the spatial attributes for a particular mansion located on a limited land funds over time. Based on the results of this visual analysis, the paper has resulted in a model of visual representation of geography objects at different levels of details over time, it is called $TLOD_S$. The empirical results in the paper demonstrate that the $TLOD_S$ are capable of answering questions about the evolutionary history of geography objects at different levels of details over time. The $TLOD_S$ model is not only capable of visually rendering features at various levels of details, but also able to visually represent the $EHGO_S$ at $DLOD_S$. In addition, the $TLOD_S$ model needs to be complemented with design, style, size, and color-coded components for the geography objects, and in particular can further expand the object classes for various types of objects according to the real world.

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