Proposing the combination of spatial components to build residential buildings at levels of details in 3D space

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Abstract

In the long historical development of urban architecture is always diverse in terms of type, style, and color. This is a major challenge for GIS researchers of 0-1-2-2.5-3-3.75-4D space. How can they perform residential buildings in a 2D computer screen? This great challenge is reflected in such aspects as shapes of buildings, storage of space of buildings, update the space of buildings, and query the space of buildings. This article systematizes the related researches, classifies existing GIS models, reviews and recommends the combination of spatial components for the construction of residential buildings at the detailed level (LODs) in three-dimensional (3D) space, so receivable result is a GIS new data model, this new model is called IOLODs. The paper installs experimental combinations of spatial components to become residential buildings. This experimental setup is deployed on Oracle 11G and C#, resulting in a visual representation of residential buildings at LODs in 3D space. The empirical results show that integrating spatial components into the construction of residential buildings in new urban planning is a practical and correct work.

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Từ khóa
residential buildings, combination of spatial components, LODs, IOLODs.

1 Introduction

The population has grown rapidly and especially the influx of immigrants into big cities has increased, thus making urban architecture more and more overloaded. Recognizing this importance, the paper proposes spatial components to building residential buildings in an urban area. The combination of these spatial components in the construction of residential buildings is a major challenge for space and time GIS researchers. This great challenge is reflected in the following aspects, the shape of the buildings is very rich and diverse, the mode of storage of space of buildings, the method of update the space of buildings and the space query of buildings.

In order to build a high-rise building, we have to combine spatial components such as Point (Ps), Line (Ls), Surface (Ss), Triangle (Ts), and Body (BP and BCs). This article uses the B-REP (Boundary Representations) method to represent 0-1-2-2.5-3-3.75D objects based on predefined elements, including: Ps, Ls, Ss, Ts, and BP and BCs. In it, Lines can be straight line segments, arcs, or circles; Surfaces can be flat polygons, faces made of circular arcs, cone faces, or cylindrical faces; Body is the expansion of faces, representing 3D blocks, and blocks that can be box, cone, cylindrical, combination of these blocks or any block [1, 2]. B-REP is suitable for space objects which have usual, artificial, and scalar shapes.

The main idea of this article is a combination of space components to construct of residential buildings located in a metropolitan area in space at the detailed levels (LODs). Spatial components that include Ps, Ls, Ss, Ts, and BP and BCs (solid, body or prism) are the basic components of the 3D geographical science space. The combination of these components is aimed at minimizing spatial data storage to assist in solving some of the problems of limited land fund management.

The rest of this article is organized as follows. Section 2 carries out the systematization of related studies, leads to the classification and comparison of models, leads to comments, and leads to new proposals. Section 3 analyzes and proposes spatial components for the integration into residential buildings located in urban areas, and through this analysis and aggregation we obtain the IOLODs model. The IOLODs model is capable of answering users' questions about the space of buildings that are visualized at different levels of details. Section 4 presents several experiments to check the usefulness of combining spatial components and the usefulness of the IOLODs model. Section 5 presents the results and directions for future development. The last part is the reference.

2 Overview of GIS data models

The construction of data models plays an important role in the length of history of urban architecture development and is a key in GIS applications of space and time. We systematize the GIS data models by each type and make some comparisons according to the most common criteria.

2.1 Systemizing GIS data models for each type of model

To represent well on spatial objects of 0-1-2-2-3-3.75-4D with boundaries, the B-REP method is a good choice. This method performs a 3D object based on predefined elements, including: Point, Line, Surface, Solid, and this method is suitable for representing 3D objects have normal and scalar shape. The data models proposed by the authors from the past to the present have applied the B-REP method, which includes UDM spatial data model proposed by author Coors in 2003 [3]; Cadastral 3D model proposed by group of authors Yuan Ding and colleagues in 2017 [4]; The TUDM model proposed by group of authors Anh N.G.T and colleagues in 2012 [5]; The VRO-DLOD3D model was proposed by group of authors Dang.P.V colleagues in 2017 [6]; The CityGML model was proposed by group of authors Groger colleagues in 2007 [7]; group of authors Kolbe and colleagues have expanded the CityGML model in 2009 [8]; group of authors Biljecki and his colleagues improved the CityGML model by 2016 [9]; The group of authors Dang.P.V and his colleagues proposed the ELDM model for 2.5D objects in 2011 [10]; The group of authors Anh N.G.T and colleagues proposed ELUDM for 2.5-3D objects in 2011 [11]; group of author Löwner and colleagues proposed a new LoD and multi-representational concept for the CityGML model in 2016 [12]; The CityGML-TRKBIS.BI model was proposed by group of authors Aydar and colleagues to meet the need to establish 2-2.5-3D objects at national level by 2016 [13].

To represent 3D objects with voxel elements such as pixels in GIS 2D, the voxel method is a good choice. This method performs a 3D object based on the idea of splitting an object into child elements, each child element being called a voxel [14]. An element is considered a geospatial and is assigned an integer [15]. The models proposed by the authors from the past to the present have applied the voxel method, including the 3D array model proposed by Rahman in 2005 [1, 2]. The model has the simplest data structure used to perform 3D objects. Elements in 3D array have one of two values of 0 and 1. Where 0 describes the background value, 1 describes the value that each element in the 3D array is occupied by the 3D object. If a 3D object is scanned in a 3D array that the elements of the array are initialized to 0. After scanning on a 3D object, elements with a value of 1 perform the information for the 3D object. The Octree model proposed by Gorger and colleagues in 2004 [2][16]. Octree is an extension of the quadtree into the octal tree. Octree representation is a 3D model based on volume. 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. In the tree, each node is node or leaf or 8 seedlings. Each seedling tree will be checked before being divided into 8 different seedlings tree.

To represent 3D objects by combining the basic 3D blocks proposed by Rahman in 2008 [1, 2]. The CSG model represents a 3D object by combining predefined 3D elements. The basic 3D blocks use formal 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, and the CSG does not conform to the performance for the objects have unusual geometric shapes.

2.2 Table classification of models

Through the systematization and classification of GIS data models in section 2.1 gives us a clear view of the evolution of GIS data models proposed by the authors in the past to present. We find that these models mainly use the B-REP method. This method represents a 3D object based on predefined elements, including: Point, Line, Surface, Solid, and this method is suitable for representation 3D objects which have normal and scalar shape. We make the table classification GIS models as follows (table 1).

Table 1 Classification of GIS data models

Type of model	The names of models
B-REP	UDM Model, 3D Cadastral Model, TUDM Model, VRO-DLOD3D Model, CityGML Model, Improved the CityGML Model, ELUDM Model for 2.5D and 3D objects, Multi-representational concept (MRC) for CityGML model, CityGML-TRKBIS.BI model extending from CityGML model
VOXEL	3D Array Model, Octree Model
CSG	CSG Model

2.3 Comparison table between models

To represent spatial objects (including residential buildings, villas, apartments, etc.) in 3D space, modeling method is the key to success. Criteria for modeling are models that must be able to represent spatial objects in 3D space according to the criteria of the external representation, the inner representation, the representation of the levels of details which also has the ability to store spatial data, store time data, and store semantic data. In 2013, the group of authors Gia.T.A.N. and associates [20] presented a summary of the 3-4D GIS data models, in which this author group proposed a summary of the criteria that each 3-4D GIS data model must satisfied. Those criteria including representation of the surface of objects, representation of the interior objects, representation of key elements, representation of dimension of data, application to applications, spatial data structure, spatial attribute queries, object positioning queries, semantic queries. Then by 2017, the author group T.Nguyen-Gia and colleagues [21] brought out a brief survey of 3-4D GIS data models popular today with comparative tables which were according to characteristic criteria such as representation kinds of surface, representation of the interior objects, ability to triangularity, inability to triangularity, model foundation, data storage size, and ability to apply for present applications. Based on the criteria set forth by the two author groups mentioned above which will be used as a premise for this article, and through the systematization and classification of GIS data models above, we compiled two tables comparing the most common criteria between the models to be the basis for future recommendations. In it, table 2 compares the models according to the criteria: exterior representation, inner representation, and representation of detailed levels. Table 3 compares the models according to the criteria: spatial, temporal, semantic, and residential data storage.

Table 2 Comparison between models according to the criteria: exterior representation, inner representation, and representation of detailed levels.

The names of models	Exterior representation	Inner representation	Representation of detailed levels
UDM	Triangulation	No	No
3D Cadastral	Triangulation	Yes	No
TUDM	Triangulation	Yes	No
VRO-DLOD3D	Triangulation	Yes	Yes
Improved the CityGML	Triangulation	Yes	Yes
ELUDM for 2.5-3D	Triangulation	Yes	Yes
Multi-representational concept (MRC) for CityGML	Triangulation	Yes	Yes
CityGML-TRKBIS.BI	Triangulation	Yes	Yes
3D Array	Yes	No	No
Octree	Yes	No	No

Table 3 Comparison between models according to the criteria: spatial, temporal, and semantic data storage.

The names of models	Spatial data storage	Temporal data storage	Semantic data storage
UDM	Triangulation	No	No
3D Cadastral	Yes	No	Yes
TUDM	Yes	Yes	No
VRO-DLOD3D	Triangulation	No	Yes
Improved the CityGML	Yes	No	Yes

The names of models	Spatial data storage	Temporal data storage	Semantic data storage
ELUDM for 2.5-3D	Yes	No	No
Multi-representational concept (MRC) for CityGML	Yes	No	Yes
CityGML-TRKBIS.BI	Yes	No	Yes
3D Array	No	No	No
Octree	No	No	No

3 Proposing objects and developing an IOLODs model

Through the systemization, classification, and comparison the models in section 2, we found that the above models mainly apply the B-REP. In general, these models focus on the management and exploitation of spatial, temporal, semantic, population objects and relationships. However, the big challenge now is how to show inhabitant housing in urban areas in more detail in the spatial components, from there new managers have the opportunity to manage the spatial objects at the level of detail to serve for the future planning of urban development policies. From the above challenges, we propose a combination of spatial components to build residential buildings at levels of details in 3D space.

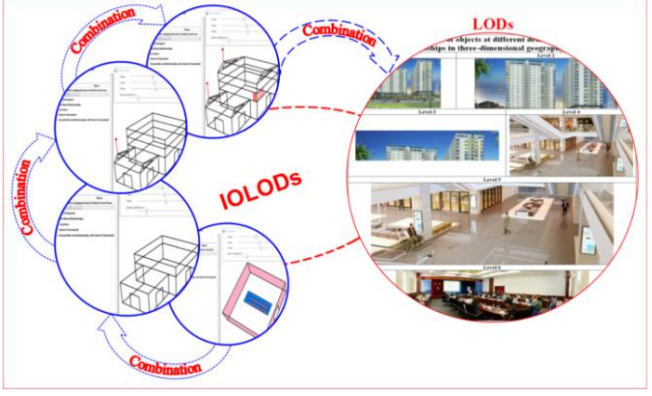


Figure 1 Composite of spatial components at detailed levels

3.1 Proposing objects

To build a high-rise building in a 3D geographical science space, we need to have the following spatial components: Point (Ps) is used to represent the object as a light bulb, lightning rod lightning, etc. The line (Ls) is used to represent the object is a flag pole, lamp post, fence, balcony, etc. Surface (Ss) is used to represent objects such as windows, doors (main or auxiliary), roofs, bricks, balconies, etc. Triangle (Ts) is used to represent the object windows, roof windows, canopy of the window, etc. Solid (body, solid, and prism are abbreviated of BP and BCs) used to represent the object is room, floor, balcony, roof, etc. Example describes a high-rise building by combining the proposed space components, see figures 1 and 2 below.

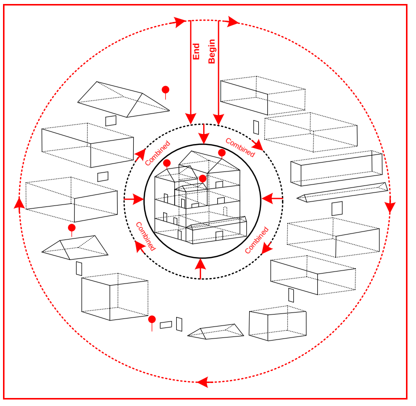


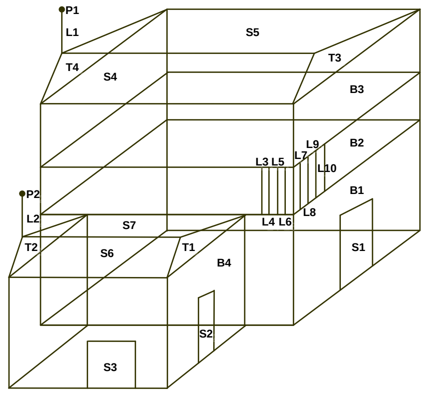
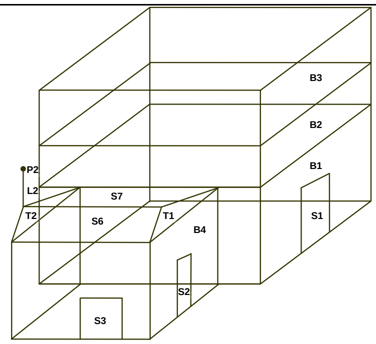
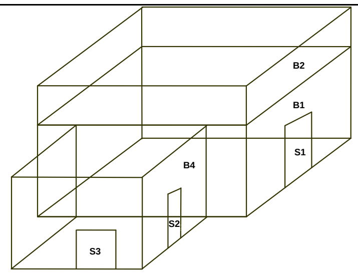
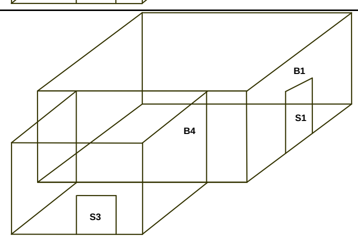
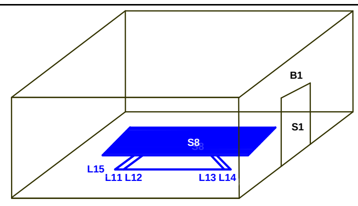
Figure 2 The process of processing basic space components to incorporate residential buildings on a limited land fund

3.2 Building IOLODs data model

3.2.1 Proposing integration of spatial objects

The proposition of combining space components to form residential buildings is a practical practice. Every spatial object in a geographical science space such as Ps, Ls, Ss, Ts, and BP and BCs, has a close relationship with each other to form different levels of details. At the level of detail used to observe and trace traces. Policy makers develop urban architecture need to collect detailed information of objects to serve the extraction, storage and updating of spatial objects. In addition, users can observe spatial objects at different levels of details and at different looking angles to meet specific purposes. The objective of the article is to build the IOLODs model (see figure 3) to satisfy the criteria for representing residential buildings at various levels of details to serve the management of urban technical infrastructure. An illustration of the IOLODs model for LODs, IOLODs represents the "SunnyBee" villa displayed at five different levels of details (see table 4).

Table 4 Representing the SunnyBee villa at five detailed levels and presents it to the database

LODs	**Figure of the SunnyBee villa**	**Present the SunnyBee villa to the database**					
		BP	**BCs**	**Ss**	**Ts**	**Ls**	**Ps**
1		**SB1**	**B1** **B2** **B3** **B4**	**S1** **S2** **S3** **S4** **S5** **S6** **S7**	**T1** **T2** **T3** **T4**	**L1** **L2** **L3** **L3** **L4** **L5** **L6** **L7** **L8** **L9** **L10**	**P1** **P2**
2		**SB1**	**B1** **B2** **B3** **B4**	**S1** **S2** **S3** **S6** **S7**	**T1** **T2**	**L2**	**P2**
3		**SB1**	**B1** **B2** **B4**	**S1** **S2** **S3**			
4		**SB1**	**B1** **B4**	**S1** **S3**			
5		**SB1**	**B1**	**S1** **S8** **S9**		**L11** **L12** **L13** **L14** **L15** **L16**	

3.2.2 Development of IOLODs data model

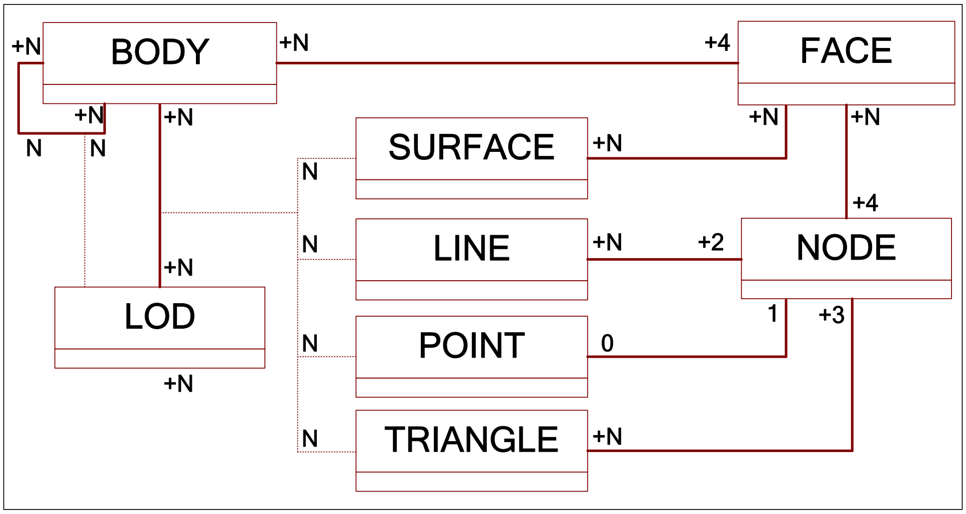


Figure 3 IOLODs data model

From figure 3, we disassociate this IOLODs model into the following relations:
BODY(#IDB, DESC, HEIGHT, TYPESHAPE, ARRAYNODE)
SURFACE(#IDS, DESC, TYPESHAPE, ARRAYNODE)
LINE(#IDL, DESC, TYPESHAPE, ARRAYNODE)
POINT(#IDP, DESC, TYPESHAPE, ARRAYNODE)
TRIANGLE(#IDT, DESC, TYPESHAPE, ARRAYNODE)
NODE(#IDN, X, Y, Z)
LOD(#IDLOD, NAME)
BODYLOD(#IDBP, #IDBC, #IDLOD)
SURFACELOD(#IDBP, #IDS, #IDLOD)
LINELOD(#IDBP, #IDL, #IDLOD)
POINTLOD(#IDBP, #IDP, #IDLOD)
TRIANGLELOD(#IDBP, #IDT, #IDLOD)
Notation: # is primary key.

3.2.3 Creating queries

The IOLODs data model is capable of querying spatial objects at detailed levels. Hereafter we illustrate three typical queries, which are a testimony to the objective satisfaction of this paper.

Query 1: Finding and displaying the "SunnyBee" Villa, the display information includes: the shape of the villa.

Query 2: Finding and displaying the "SunnyBee" Villa at the given detailed levels LODs = x (x: 1, 2, 3, and 5), the display information includes: the shape of villa at detail levels LODs = x (x: 1, 2, 3, and 5).

Query 3: Finding and displaying the "SunnyBee" Villa at the given detailed levels LODs = 4, the display information includes: the shape of villa at detail levels LODs = 4.

4 Experiment

Through analyzes and recommendations in section 3, this paper combines spatial components to represent spatial residential buildings over space at different levels of details to obtain a new data model. This new data model is called IOLODs (see figure 3). In this section, we use Oracle 11G to install the IOLODs data model and use the Oracle spatial data type to store spatial data, this type of spatial data makes the data display time 3D buildings in the 3D geographical science space became faster and combined with C# [17,18,19] to develop applications that visualized spatial objects at different levels of details. In it, we illustrate query 2 with the form described by two parameters: input and output parameters. Spatial and semantic data collected by this paper by manual methods connotations entering data of spatial coordinates and semantic by hand. Thus, the spatial and semantic data components in this article are empirically simulated to verify the usefulness of the proposed model (see figure 3).

Query 2: Finding and displaying the "SunnyBee" Villa at the given detailed levels LODs = x (x: 1, 2, 3, and 5), the display information includes: the shape of villa at detail levels LODs = x (x: 1, 2, 3, and 5).

Input: Name of the "SunnyBee" villa and details levels

Output: Shape of the "SunnyBee" villa at the detailed levels LODs = x (x: 1, 2, 3, and 5). See figure 4, 5, 6, 7.

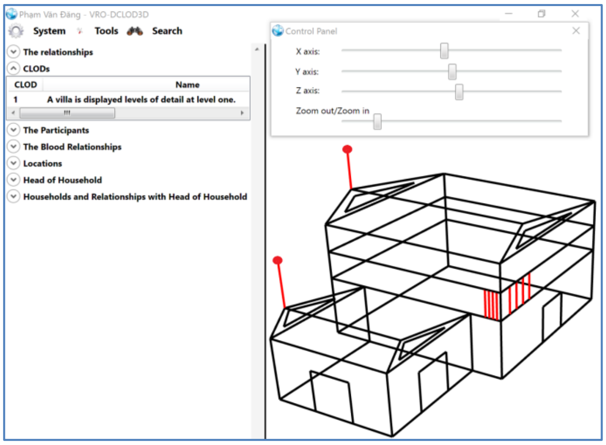


Figure 4 Show SunnyBee villa at level 1

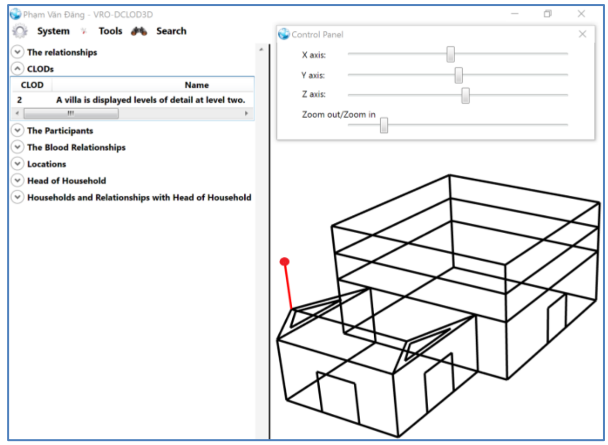


Figure 5 Show SunnyBee villa at level 2

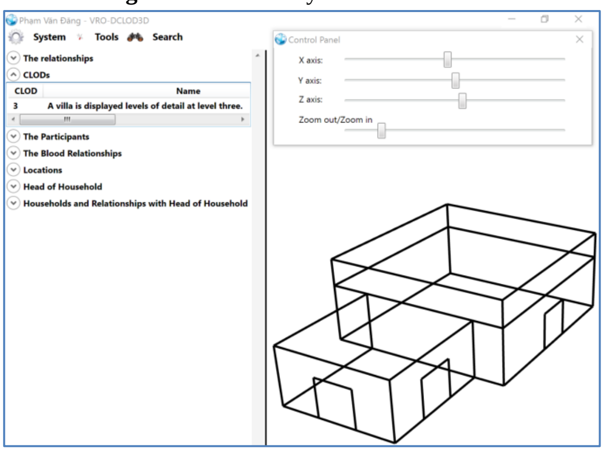


Figure 6 Show SunnyBee villa at level 3

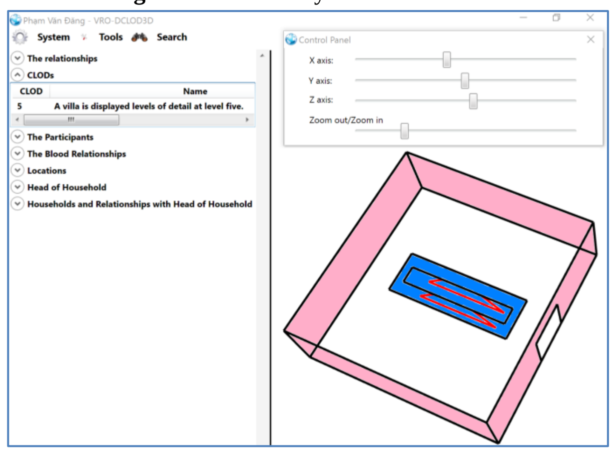


Figure 7 Show SunnyBee villa at level 5

5 Conclusions

This paper has systematized, classified, and compared GIS data models that have been proposed by several groups of authors in the past. Through classification and comparison GIS data models, we find that these models mainly use the B-REP method; this method is well suited for the representation of spatial objects which has a usual and scalar shape. This paper proposes a combination of spatial components to construct residential buildings at the detail of levels in a 3D space that applied B-REP method which is a suitable work and meaningful scientific. Since then, the article has created a class of spaces to represent residential buildings in the form of combinations of geometries such as blocks, faces, lines, and points combined with layers of different levels of details, receivable result is a GIS new data model, this new model is called IOLODs. The IOLODs model is not only capable of supporting spatial data storage but also capable of answering questions about spatial object combinations at detailed levels. Finally, this article has been the experimental result on query 2 on visual representation of spatial objects at the levels of details of a residential building. In addition, the IOLODs data model needs to be developed to combine time subclass into classifying objects along with relationships over time in 3D geographical science space to serve multiple different contexts.

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Đề xuất tổ hợp các hợp phần không gian để xây dựng tòa nhà dân cư tại các mức chi tiết trong không gian 3 chiều

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Tóm tắt Trong chiều dài lịch sử phát triển của kiến trúc đô thị luôn luôn đa dạng về chủng loại, kiểu dáng, và màu sắc. Đây là thách thức lớn cho các nhà nghiên cứu GIS không gian 0-1-2-2.5-3-3.75-4D là làm sao họ có thể biểu diễn các tòa nhà dân cư ở một khu đô thị vào trong máy tính màn hình 2 chiều? Thách thức lớn này được thể hiện ở các khía cạnh như hình dạng các tòa nhà, lưu trữ không gian các tòa nhà, cập nhật không gian tòa nhà, và truy vấn không gian các tòa nhà. Bài báo này thực hiện hệ thống hóa các công trình nghiên cứu liên quan, phân loại các mô hình GIS hiện có, đưa ra các nhận xét, và đề xuất việc tích hợp các hợp phần không gian để xây dựng tòa nhà dân cư tại các mức chi tiết trong không gian 3 chiều. Kết quả nhận được là một mô hình dữ liệu GIS mới. Mô hình mới này có tên là IOLODs. Bài báo cài đặt thực nghiệm tổ hợp các hợp phần không gian để trở thành tòa nhà dân cư. Việc cài đặt thực nghiệm này được triển khai trên Oracle 11G và C#, các kết quả có được là hiển thị trực quan các tòa nhà dân cư tại các mức chi tiết trong không gian 3 chiều. Qua các kết quả thực nghiệm, chúng ta thấy được việc tích hợp các hợp phần không gian vào xây dựng các tòa nhà dân cư trong quy hoạch đô thị mới là một việc làm thiết thực và đúng đắn.

Từ khóa tòa nhà dân cư, tổ hợp các hợp phần không gian, các mức chi tiết, mô hình IOLODs